U.S. DEPARTMENT OF COMMERCE
National Technical Information Service

PB-289 758

Attainment and Maintenance of TSP (Total Suspended Particulate) Standards in Puerto Rico

Engineering-Science, Inc, McLean, VA

Prepared for

Puerto Rico Environmental Quality Board, Santurce

Oct 78

PB 289758

EPA·902/4·78·004

Attainment and Maintenance of Total Suspended Particulate Standards in Puerto Rico

Final Report

REPRODUCED BY
NATIONAL TECHNICAL
INFORMATION SERVICE
U.S. DEPARTMENT OF COMMERCE
SPRINGFIELD, VA. 22161

October 1978

U.S. ENVIRONMENTAL PROTECTION AGENCY
REGION II
PUERTO RICO ENVIRONMENTAL QUALITY BOARD

ATTAINMENT AND MAINTENANCE

OF

TSP STANDARDS IN PUERTO RICO

Submitted to

U.S. Environmental Protection Agency
Region II Offices
New York City, New York

and

Puerto Rico Environmental Quality Board
Santurce, Puerto Rico

Submitted by

Engineering-Science
7903 Westpark Drive
McLean, Virginia 22102

December 1, 1978

TABLE OF CONTENTS

		Page
CHAPTER I	INTRODUCTION	
	Background	I-1
	Pollutants Analyzed - Study Years	I-1
	Study Area	I-1
	Methodology	I-3
	Control Strategies Analyzed	I-3
	Organization of Report	I-4
		I-5
CHAPTER II	EMISSION INVENTORIES	
	Point Source Inventory	II-1
	Area Source Inventory	II-1
	Summary of Emissions by Source Category	II-1
		II-2
CHAPTER III	MODEL VALIDATION	III-1
CHAPTER IV	DISCUSSION OF RESULTS	IV-1
	Source Category Contributions to Predicted Air Quality Levels	IV-3
	Catano Nonattainment Study Area	IV-3
	Guayanilla-Penuelas Nonattainment Study Area	IV-4
	Maintenance Areas	IV-6
	Sensitivity Analysis of 1990 Predictions	IV-34
CHAPTER V	CONTROL STRATEGY DEVELOPMENT	V-1
	Comparison of Emission Data	V-1
	Impact on Air Quality	V-3
	Summary of Control Strategy Development Tests	V-6
CHAPTER VI	SUMMARY AND CONCLUSIONS	VI-1

LIST OF TABLES

Table	Title	Page
II-1	Emission Source Categories and Applicable Particulate Regulations	II-3
II-2	Study Areas	II-5
II-3	Summary of Growth Factors for Puerto Rico	II-6
II-4	Municipalities Included in the Northeastern Study Area	II-7
II-5	Municipalities Included in the Southern Study Area	II-9
II-6	Municipalities Included in the Northwestern Study Area	II-11
II-7	Source Category Contributions to the Emission Inventory for the Northeastern Study Area	II-13

LIST OF TABLES (cont)

Table	Title	Page
II-8	Source Category Contributions to the Emission Inventory for the Southern Study Area	II-14
II-9	Source Category Contributions to the Emission Inventory for the Northwestern Study Area	II-15
III-1	A Comparison of Predicted and Measured TSP Levels in Puerto Rico	III-2
IV-1	Source Category Contributions to Predicted Air Quality - San Juan, Munoz Rivera	IV-11
IV-2	Source Category Contributions to Predicted Air Quality - Bayamon	IV-13
IV-3	Source Category Contributions to Predicted Air Quality - Catano, Port Zone	IV-15
IV-4	Source Category Contributions to Predicted Air Quality - Catano, Las Vegas	IV-17
IV-5	Source Category Contributions to Predicted Air Quality - Guaynabo, USGS	IV-19
IV-6	Source Category Contributions to Predicted Air Quality - Guaynabo, Pump House	IV-21
IV-7	Source Category Contributions to Predicted Air Quality - Toa Baja	IV-23
IV-8	Source Category Contributions to Predicted Air Quality - Ponce	IV-25
IV-9	Source Category Contributions to Predicted Air Quality - Guananilla-Playa Guayanill	IV-27
IV-10	Source Category Contributions to Predicted Air Quality - Guayanilla-Magas Arriba	IV-29
IV-11	Source Category Contributions to Predicted Air Quality - Penuelas	IV-31
V-1	Summary of Particulate Emissions for the Control Strategies Tested Particulate Emissions	V-2
V-2	Summary of Air Quality Improvements for the Control Strategies Tested	V-4
VI-1	Summary of Predicted TSP Results	VI-3

LIST OF FIGURES

Figure	Title	Page
I-1	Puerto Rico, Designated Nonattainment Areas and Study Areas	I-2
II-1	Puerto Rico, Northeastern Study Area	II-8
II-2	Puerto Rico, Southern Study Area	II-10
II-3	Puerto Rico, Northwestern Study Area	II-12
III-1	A Comparison of Predicted and Measured TSP Levels in Puerto Rico	III-3

LIST OF FIGURES (cont)

Figure	Title	Page
IV-1	Puerto Rico Attainment Analysis All Point and Area Sources TSP - ($\mu g/m^3$) Annual Arithmetic Mean, Baseyear Conditions	IV-7
IV-2	Puerto Rico Attainment Analysis All Point and Area Sources TSP - ($\mu g/m^3$) Annual Arithmetic Mean, Assuming Compliance with Existing Regulations	IV-8
IV-3	Puerto Rico Attainment Analysis All Point and Area Sources TSP - ($\mu g/m^3$) Annual Arithmetic Mean, Implementation of All Control Strategies	IV-9
IV-4	Puerto Rico Attainment Analysis All Point and Area Sources TSP - ($\mu g/m^3$) Annual Arithmetic Mean, Projections to 1990	IV-10
IV-5	San Juan - Munoz Rivera Average	IV-12
IV-6	Predicted TSP Concentrations - $\mu g/m^3$, Bayamon	IV-14
IV-7	Predicted TSP Concentrations - $\mu g/m^3$, Catano	IV-16
IV-8	Predicted TSP Concentrations - $\mu g/m^3$, Catano	IV-18
IV-9	Predicted TSP Concentrations - $\mu g/m^3$, Guaynabo	IV-20
IV-10	Guaynabo - Pump House	IV-22
IV-11	Predicted TSP Concentrations - $\mu g/m^3$, Toa Baja	IV-24
IV-12	Predicted TSP Concentrations - $\mu g/m^3$, Ponce	IV-26
IV-13	Predicted TSP Concentrations - $\mu g/m^3$, Guayanilla-Playa	IV-28
IV-14	Predicted TSP Concentrations - $\mu g/m^3$, Guayanilla-Magas Arriba	IV-30
IV-15	Predicted TSP Concentrations - $\mu g/m^3$, Penuelas	IV-32

CHAPTER I

INTRODUCTION

BACKGROUND

The recent Clean Air Act Amendments of 1977 called for the participation of local, state, and Federal air pollution control officials to meet ambient air quality standards as expeditiously as practicable. Of paramount importance were existing nonattainment areas and, specifically, how to deal with new source growth in nonattainment areas. New source growth in areas with the potential to exceed standards was also addressed. The Act requires that responsible officials commit to an effective program to attain national ambient air quality standards by December 1982, and to maintain the standards for a reasonable time in the future.

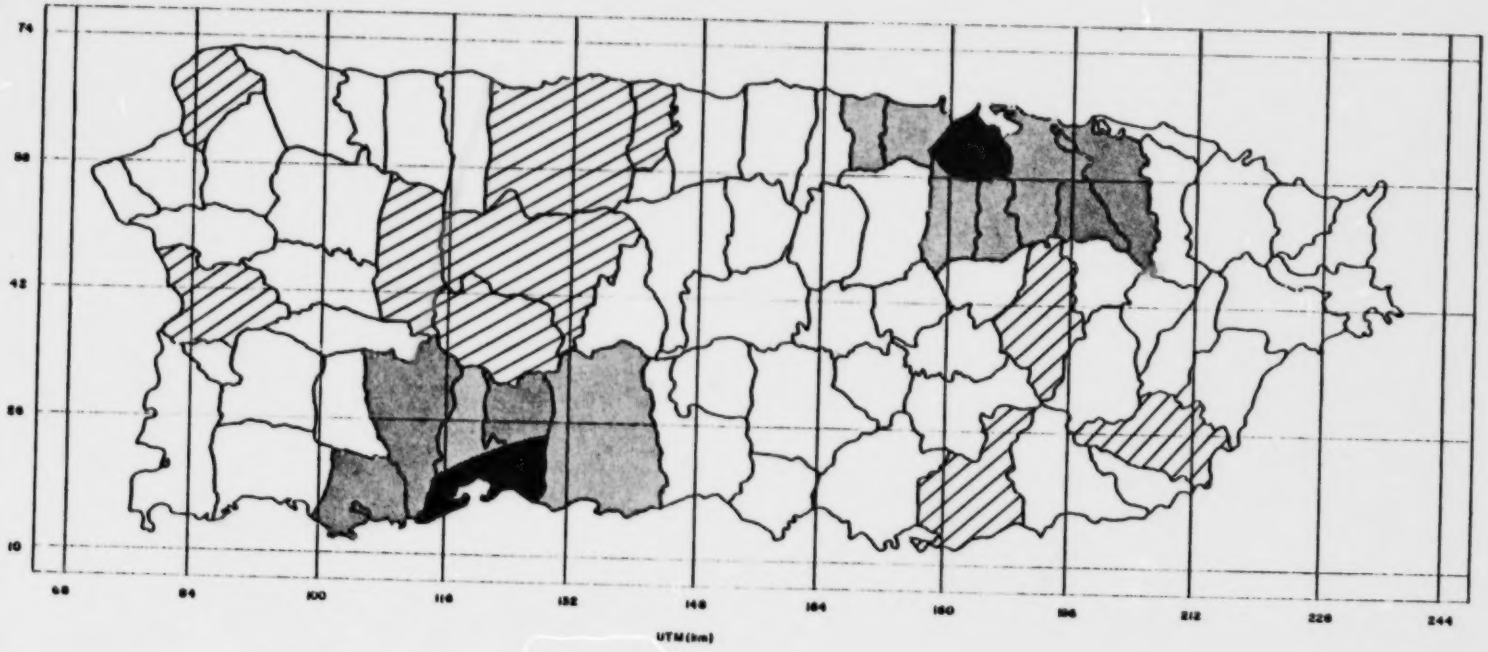
Several areas in Puerto Rico have been designated as not attaining the total suspended particulate (TSP) ambient air quality standard. These nonattainment areas are shown in Figure I-1. The Act requires that the states prepare a revision to their original State Implementation Plans (SIPs) that were previously submitted in 1972, which will show attainment of the particulate standards. As a result of this Congressional mandate, Engineering-Science (ES) has been engaged by the Environmental Protection Agency (EPA) to assist the Puerto Rico Environmental Quality Board (EQB) in conducting an engineering analysis for the attainment and maintenance of particulate levels in Puerto Rico.

POLLUTANTS ANALYZED - STUDY YEARS

Total suspended particulate matter is the only pollutant discussed in this report. A second study, not yet completed, will consider sulfur dioxide, and predict the SO_2 levels through 1990. The base year used for this analysis was calendar year 1976. Point source data had been collected as a result of previous studies completed by ES, and through a continuing update process conducted by EQB. Area source emissions that had been compiled under a previous effort correspond to about the same time period as the point source emission inventory. Emissions for this analysis were also projected through 1990. Growth estimates were obtained from industry and government officials to determine any increase in industrial activity, as well as any increases associated with population, for several areas on the island.[1]

[1] Note Page IV-3 for specific methodology.

PUERTO RICO
DESIGNATED NON ATTAINMENT AREAS* AND STUDY AREAS



LEGEND

- Designated Non Attainment Areas
- Nonattainment Study Areas
- Maintenance Study Areas

*NOTE: *Vide*, the Federal Register Vol.43, No.43 March 3, 1978, p. 9055.

FIGURE I-1

STUDY AREAS

The geographic area analyzed for this study included the entire island of Puerto Rico. In the report, we refer to the Catano nonattainment study area, which includes the San Juan municipality and some of the surrounding areas. The study areas of particular interest that were analyzed and the constituent municipalities are listed below:

NONATTAINMENT STUDY AREAS[1]	MUNICIPALITIES INCLUDED
Catano	San Juan, Catano, Bayamon, Guaynabo, Toa Baja, Dorado, Carolina, Trujillo Alto
Guayanilla-Penuelas	Guayanilla, Ponce, Penuelas, Guanica, Yuaco

MAINTENANCE STUDY AREAS	MUNICIPALITIES INCLUDED
Mayaguez	Mayaguez
Aguadilla	Aguadilla
Arecibo-Barceloneta	Arecibo, Barceloneta
Lares-Utuado-Adjuntas	Lares, Utuado, Adjuntas
Guanica	Guanica
Guayama	Guayama
Caguas	Caguas
Yabucoa	Yabucoa

METHODOLOGY

Other studies of air pollution in Puerto Rico have been completed by ES over the last several years for EPA and EQB. These studies included a base year TSP modeling analyses for calendar year 1974. Point and area source emissions were tabulated for these studies, and at the initiation of this project, a review was made of this data. As a result, several updates were made and incorporated into another inventory which represented the 1976 base year emissions used in this analysis. Our specific goal was to estimate particulate air quality levels throughout the nonattainment and maintenance study areas. Subsequently, control strategies were developed that would reduce particulate emissions, and hopefully, result in a corresponding decrease in ambient particulate levels.

[1] A maintenance analysis was also performed for each area.

A dispersion model (EPA's AQDM, representing the current state-of-the art) was used along with the emission data and meteorological data to predict ambient air quality levels. The predicted levels were compared to the measured results for the base year. A good source/receptor relationship was developed for the area. With an effective source/receptor relationship, various control strategies were tested and analyzed for the subsequent improvement made on air quality. The base year emissions were then projected to 1990 to show that the ambient air quality standards would be maintained. Concentration isopleths were drawn to show the TSP levels over the island for the base year, the control strategy scenarios, and the projection year 1990.

CONTROL STRATEGIES ANALYZED

Six strategies were analyzed for reducing particulate emissions in Puerto Rico:

- Oil fired boilers: A mass emission limit type of regulation was developed and tested;
- Solid fuel boilers: The existing mass emission limit regulation was tightened;
- Nonprocess sources:[1] This regulation is, in fact, a correction of an existing EQB regulation, and requires a percent reduction in emissions (use of a control device to eliminate dust);
- Asphalt dryers: A stack gas concentration limit was established;
- Elimination of cane burning: By 1990, a prohibition of burning on the south coast of the island that has been agreed to by the sugar industry; and
- Elimination of open burning: Prohibition of any trash burning, particularly at municipal landfills.

[1] The EQB definition for a nonprocess source is a manufacturing process which does not involve a chemical reaction; e.g., rock crushers.

Quantitative limits for these strategies are described in Chapter II. In addition to the new regulations, an analysis was made of compliance with the existing regulations. Enforcement of the visible emission requirement would reduce particulate emissions for a number of plants.

ORGANIZATION OF REPORT

This study has not included an analysis for the time period 1979 to 1982, critical dates mentioned in the Clean Air Act Amendments. Also, the concept of "reasonable further progress" toward attainment of the standards has not been addressed. These two important concepts will be discussed later either in subsequent reports or at the public hearings.

In Chapter II of the report, the inventory data used in the analysis has been discussed. This chapter contains those changes in emissions expected as a result of implementing each of the control strategies tested. In Chapter III, we describe the dispersion model and source-receptor relationship; i.e., the comparison of the theoretical modeling results and the measured field data routinely collected by EQB. The detailed results for each of the study areas are shown in Chapter IV. Figures depicting the concentration isopleths are also included in that chapter. Chapter V represents a brief summary of the strategies tested and a comparison of the base, compliance, strategy, and 1990 scenarios. Chapter VI contains the summary and conclusions.

All tasks involved in the completion of this study were performed by the staff of Engineering-Science, McLean, Virginia. The report is a scientific and impartial evaluation of TSP air quality in Puerto Rico and does not reflect or advocate any particular position of view by the authors.

CHAPTER II

EMISSION INVENTORIES

POINT SOURCE INVENTORY

The point source inventory used in this analysis was generated in October 1977 and was the result of a series of file updates that were being undertaken by EQB as part of their routine file maintenance procedure. Many refinements were made to the basic point source file through the use of update transactions. At the beginning of this project, ES assisted EQB in processing a large set of transactions that would complete the file for the period of interest, initially 1975. Thousands of transactions were processed with information gleaned from company air pollution permits, which are renewed and reviewed on a regular basis. The completed file was later judged by EQB and ES to better represent conditions existing in 1976.

Basically, the inventory consists of some 5,000 computerized records, forming a standard file on more than 600 plants or companies, with individual process description and stack data for over 1,500 emission points. The information is arranged in EIS/P&R format and was easily processed using standard CDHS programs.

AREA SOURCE INVENTORY

The area source inventory was compiled in a previous study which had identified those portions of the island having a potential for exceeding the air quality standards. The inventory consisted of information, on a municipality level, related to emission categories such as commercial/institutional and light industrial fuel use, open burning, aircraft and vessel operations, traffic on paved and unpaved roads, and agricultural burning. Some municipalities, such as San Juan, Ponce, and Mayaguez, had been subdivided to provide an added level of detail.

Better estimates for vehicle miles traveled on paved and unpaved roads were developed by reading a computer tape supplied by the Highway Authority, containing link specific data such as highway segment length and average daily traffic. It appeared that previous estimates for unpaved roads were high, but that estimates for paved roads were somewhat similar. Emissions appearing in the report reflect the more recent data.

Important emission categories in the area source inventory were agricultural burning, especially in the southern half of the island, open burning (including dumps), and paved and unpaved roads. These four area sources were significant even when compared to total point source emissions.

Preliminary estimates of air quality in the Ponce and Guayanilla areas indicated that the model was underpredicting by a considerable amount there. It appeared that, considering the dryness of the climate, the emission factors for paved and unpaved roads were not suited to this environment. Previously, the emission factor from AP-42 for unpaved roads, which is dependent on the number of days with rain, had been calculated using an island-wide average of 200 days. Rainfall at some locations on the southern coast may be measured on as little as 50 days, according to climatological data published by the U.S. Department of Commerce. ES doubled the emission factors for paved and unpaved roads to account for the dryness, and computer predictions then corresponded better to the measured ambient data.

SUMMARY OF EMISSIONS BY SOURCE CATEGORY

Individual emission points in EIS/P&R inventories are characterized by an eight-digit Source Classification Code (SCC) assigned by agency personnel when source information is entered into the computer file. Each SCC represents a specific function within a broad source category. Classification of sources by their SCC enabled several source categories to be analyzed with regard to emissions under present operating conditions, existing regulations, proposed regulations, and future growth. Table II-1 summarizes the point source categories considered, as well as the area source categories, and the applicable regulations, both existing and proposed. All sources in the file were considered to be included in one and only one source category.

Emissions under each of the proposed regulations or strategies were obtained through an analysis of production rate and present level of control for each category on a point-by-point basis. For the compliance and strategy case, this analysis was performed by computer, using mathematical relationships to represent the regulations. Only the estimates showing a decrease in emissions were considered. If the calculations indicated that allowable emissions were greater than actual emissions, then actual emissions were used for compliance or strategy estimates. Sources exempted from the 99%

TABLE II-1

EMISSION SOURCE CATEGORIES AND APPLICABLE PARTICULATE REGULATIONS

SOURCE CATEGORY	APPLICABLE REGULATIONS	
	EXISTING	PROPOSED
Liquid Fuel Boilers	20% opacity	0.30 lb/10^6Btu
Solid Fuel Boilers	0.30 lb/10^6Btu	0.25 lb/10^6Btu
Process Sources	Process weight table	(none proposed)
Nonprocess Sources	20% opacity	99% control
Asphalt Dryers	20% opacity	0.12 gr/dscf
Quarrying, Sand/Gravel	80% control[1]	99% control
Incinerators	0.2 lb/100 lb 0.4 lb/100 lb	(none proposed)
Agricultural Burning	none	Elimination
Open Burning	none	Elimination

[1] Reflecting good operating practice.

nonprocess control strategy were the emission points that could be identified as stockpiles, either through the SCC or a process description. These sources were brought into an 80% control condition under the compliance case to reflect good operating practice, as required under existing regulations.

For calculating compliance emissions under the 20% opacity limitations applicable to some sources, a mass emission rate was substituted based on data given in EPA publications.[1,2] The data consisted of relationships between opacity and mass emission rates for several types of sources. The relationships used in this study are given below:

[1] Measurement of the Opacity and Mass Concentration of Particulate Emissions by Transmissometry, U.S. Environmental Protection Agency, EPA-650/2-74-128, November 1974.

[2] Optical Properties and Visual Effects of Smoke-Stack Plumes, U.S. Department of Health, Education, and Welfare, 999-AP-30, 1967.

1. Liquid fuel boilers — 0.08 grains/ft^3
2. Nonprocess sources — 0.10 grains/ft^3
3. Asphalt drying — 0.13 grains/ft^3

The value for nonprocess sources was based on an average value for a range of sources.

Projections to 1990 were handled in the manual mode by associating with each emission point a growth factor based on the company's Standard Industrial Classification (SIC) code. Emissions were then multiplied by this growth factor. The four-digit SIC is used to identify the type of plant which operates the source.

Specific growth information was available from three major industries on the island: sugar processing, asphalt batching, and power generation. The indication from asphalt and sugar companies was that there would be no growth in total output in terms of emissions over the period. The power company plans to satisfy increasing demand, projected to 1990 to be about 180% of 1976 levels, by increasing output from existing stations, at least until 1988.

The U.S. Department of Commerce routinely publishes growth projections by SIC to assist in future planning. ES used this information for other sources in the master file when a specific factor could be found. If an SIC factor could not be found, ES used a factor of 4.5% per year increase reflecting the growth in Gross National Product expected through 1985.[1] Table II-3 presents the factors used to project 1976 emissions to 1990 levels.

In the point source master file there were about 650 points with emissions of particulate matter greater than or equal to one ton per year. Total island-wide point source emissions of particulate matter were estimated at 50,000 tons per year. To keep modeling expenditures compatible with budget limitations, only those point sources emitting over 10 tons per year were modeled. The remaining sources, numbering about 260 and representing about 750 tons per year, were combined with the area source emissions from the

[1] U.S. Industrial Outlook, 1976, with Projections to 1985, U.S. Dept. of Commerce, Domestic and International Business Administration, Bureau of Domestic Commerce, January 1976.

nearest municipality. Furthermore, three general areas of the island were considered separately as individual units with their own emission inventories and meteorological conditions. For each attainment or maintenance area, the appropriate emission inventory and meteorological data were used. The study areas considered were the geographic portions of the island listed in Table II-2 and illustrated in Figures II-1 through II-3; some degree of overlap occurs. Tables II-4 through II-6 give the municipalities included in each study area.

TABLE II-2

STUDY AREAS

GEO-LOCATIONS	RECORDING SITE FOR METEOROLOGICAL DATA	NUMBER OF POINT SOURCES MODELED OVER 10 TONS PER DAY	NUMBER OF SURROUNDING MUNICIPALITIES MODELED
Northeast Quarter	Isla Verde	166	40
Northwest Quarter	Ramey AFB	64	33
Southern Half	Santa Isabel	165	55

The emissions for the three separate study areas are summarized in Tables II-7 through II-9, by major emission source category. For point sources, the highest emissions were observed from the so-called nonprocess sources and boilers. The highest emissions for the area sources were from re-entrained dust from paved roads.

TABLE II-3

SUMMARY OF GROWTH FACTORS FOR PUERTO RICO

2-DIGIT SIC GROUP		FACTORS FOR PERIOD 1976 TO 1990
20	Food - kindred products	1.94
	2051 Bread	1.25
	2052 Cookies, crackers	1.25
	2061 Cane sugar	1.00
	2062 Cane sugar refining	1.00
	2082 Malt liquors	1.84
	2085 Distilled liquors	1.84
	2095 Roasted coffee	1.25
21	Tobacco	1.94
22	Textile mill products	1.94
23	Apparel and finished products	1.94
24	Lumber and wood products	1.94
25	Furniture	1.94
26	Paper and allied products	1.94
27	Printing, publishing, etc.	1.94
28	Chemicals and allied products	1.94
	2834 Pharmaceutical preparations	1.25
29	Petroleum refining	1.94
	2951 Paving mixtures and blocks	1.00
	2952 Asphalt felts and coatings	1.25
30	Rubber and miscellaneous plastic products	1.94
31	Leather and leather products	1.94
32	Stone, clay, and glass products	1.94
	3271 Concrete block and brick	1.15
	3272 Concrete products	1.15
	3273 Ready-mixed concrete	1.15
	3281 Cut stone	1.15
	3295 Minerals and earths	1.15
33	Primary metals	1.94
34	Fabricated metal products except machinery	1.94
35	Fabricated metal products, machinery	1.94
36	Electrical machinery equipment	1.94
37	Transportation equipment	1.94
38	Professional scientific instruments	1.94
39	Miscellaneous manufacturing (all others)	1.94
4911	Electric companies	1.80

TABLE II-4

MUNICIPALITIES INCLUDED IN THE

NORTHEASTERN STUDY AREA

SAROAD CODE	NAME	SAROAD CODE	NAME
0140	Aguas Buenas	1280	Humacao
0320	Barceloneta	1420	Juncos
0360	Barranquitas	1520	Las Piedras
0400	Bayamon	1560	Loiza
0480	Caguas	1580	Luquillo
0517	Canovanas	1620	Manati
0540	Carolina	1740	Morovis
0580	Catano	1780	Naguabo
0640	Ceiba	1820	Naranjito
0680	Ciales	1860	Orocovis
0720	Cidra	2020	Rio Grande
0800	Comeria	2160	San Juan
0840	Corozal	2200	San Lorenzo
0880	Dorado	2300	Toa Alta
0940	Fajardo	2320	Toa Baja
0960	Florida	2340	Trujillo Alto
1140	Guaynabo	2420	Vega Alta
1180	Gurabo	2460	Vega Baja

FIGURE II-1

PUERTO RICO
NORTHEASTERN STUDY AREA

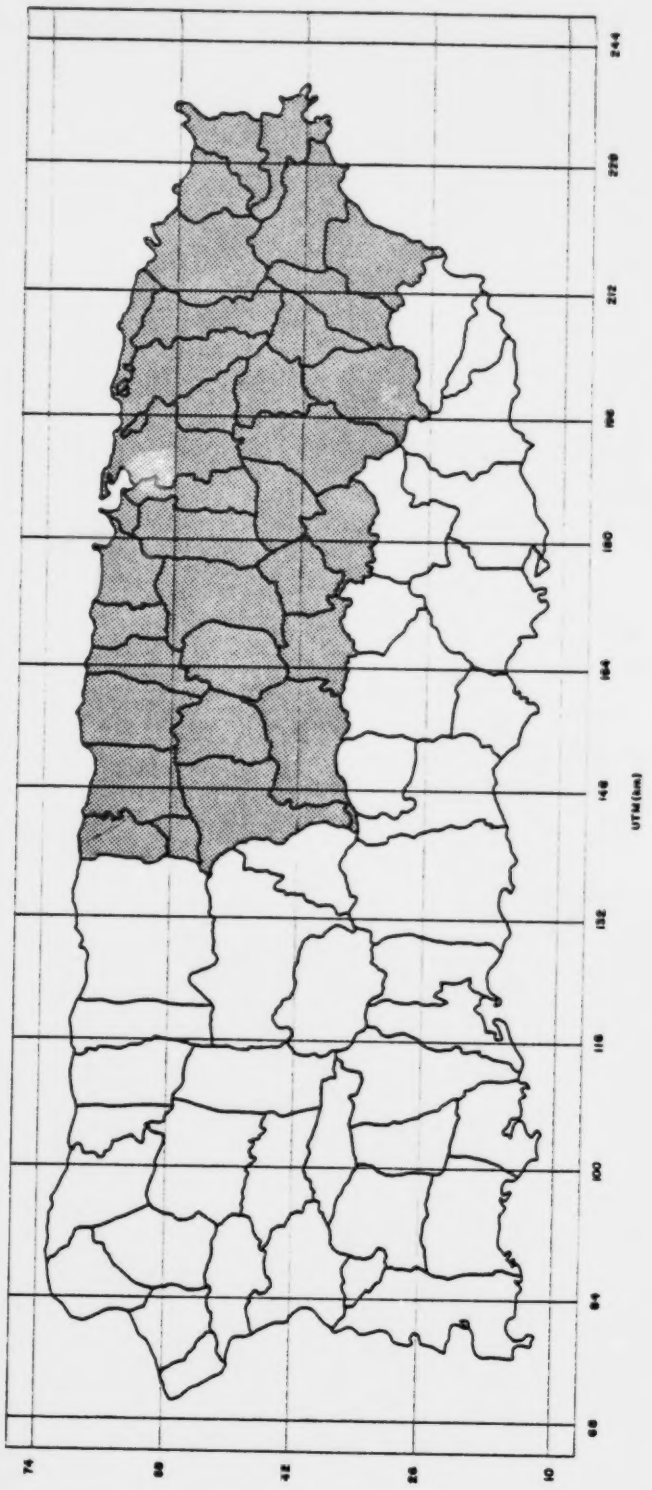


TABLE II-5

MUNICIPALITIES INCLUDED IN THE

SOUTHERN STUDY AREA

SAROAD CODE	NAME	SAROAD CODE	NAME
0040	Adjuntas	1520	Las Piedras
0180	Aibonito	1640	Maricao
0280	Arroyo	1660	Maunabo
0360	Barranquitas	1700	Mayaguez
0440	Cabo Rojo	1880	Patillas
0620	Cayey	1900	Penuelas
0720	Cidra	1940	Ponce
0760	Coamo	2060	Sabana Grande
1020	Guanica	2080	Salinas
1060	Guayama	2120	San German
1100	Guayanilla	2200	San Lorenzo
1240	Hormigueros	2280	Santa Isabel
1280	Humacao	2500	Villalba
1340	Jayuya	2540	Yabucoa
1380	Juana Diaz	2580	Yuaco
1440	Lajas		

FIGURE II-2

PUERTO RICO
SOUTHERN STUDY AREA

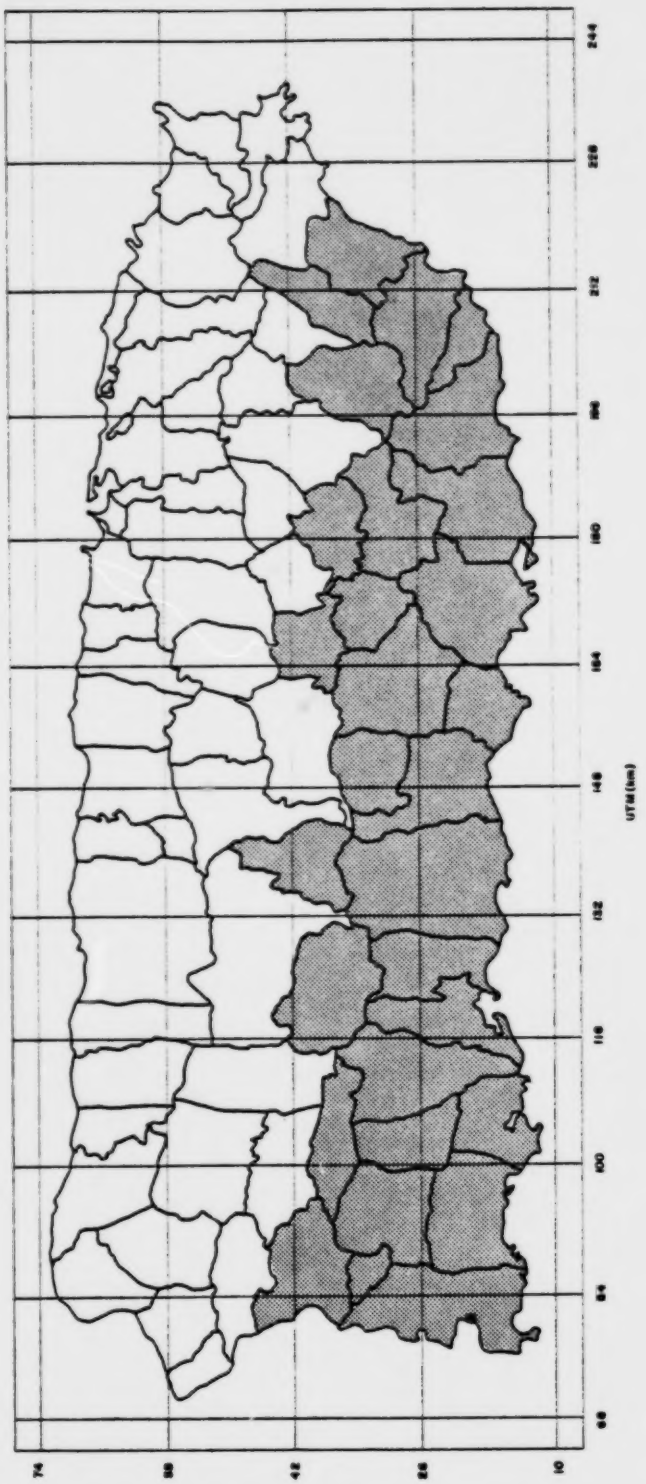


TABLE II-6

MUNICIPALITIES INCLUDED IN THE NORTHWESTERN STUDY AREA

SAROAD CODE	NAME	SAROAD CODE	NAME
0040	Adjuntas	1480	Lares
0080	Aguada	1500	Las Marias
0120	Aguadilla	1620	Manati
0200	Anasco	1640	Maricao
0240	Arecibo	1700	Mayaguez
0320	Barceloneta	1720	Moca
0500	Camuy	1740	Morovis
0680	Ciales	1860	Orocovis
0840	Corozal	1960	Quebradillas
0960	Florida	1980	Rincon
1220	Hatillo	2240	San Sebastian
1240	Hormigueros	2380	Utuado
1320	Isabela	2420	Vega Alta
1340	Jayuya	2460	Vega Baja

FIGURE II-3

PUERTO RICO
NORTHWESTERN STUDY AREA

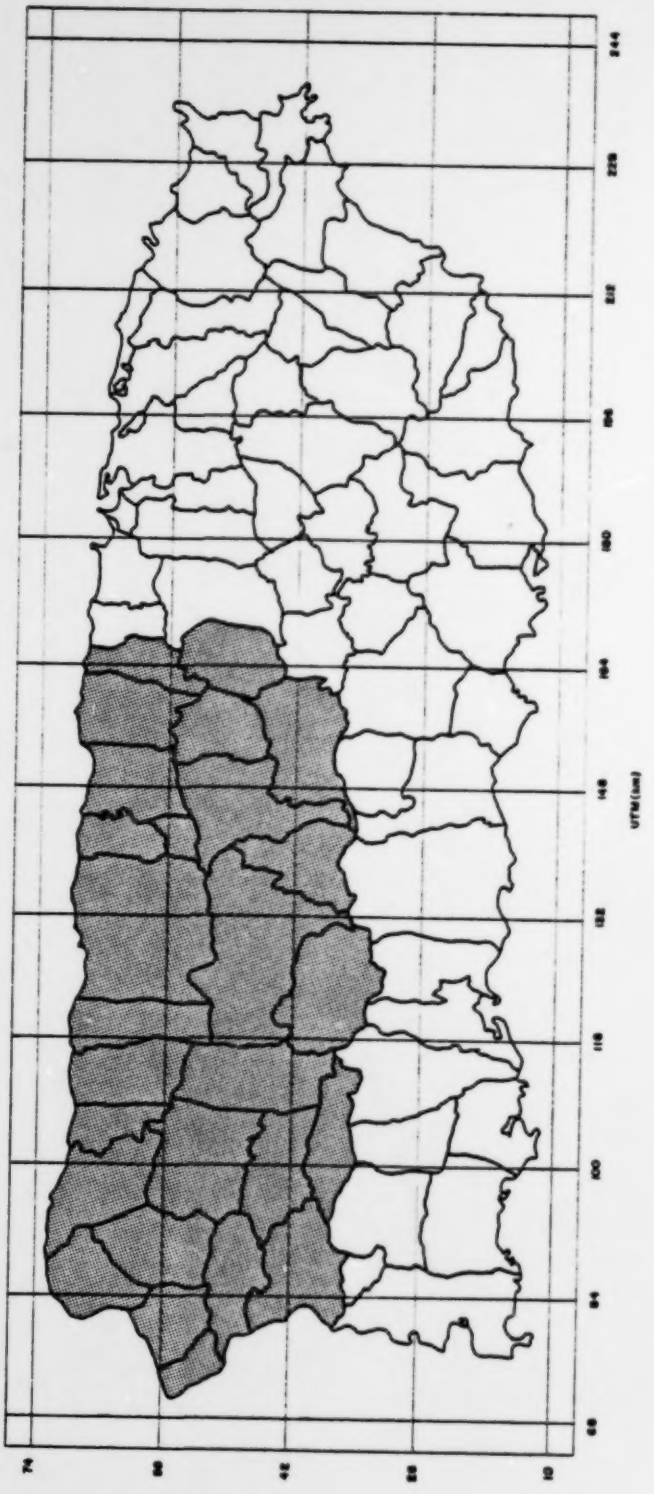


TABLE II-7

SOURCE CATEGORY CONTRIBUTIONS
TO THE EMISSION INVENTORY
FOR THE NORTHEASTERN STUDY AREA*

POINT SOURCES (Over 10 tons/year)	CONTRIBUTIONS TONS/DAY				
	BASE	COMPLIANCE	STRATEGY	REDUCTION	1990
Oil Fired Boilers	20.0	19.2	19.2	0	34.5
Bagasse Fired Boilers	0.5	0.3	0.2	0.1	0.2
Stationary Engines	2.1	2.1	2.1	0	3.8
Processes	2.9	1.7	1.7	0	2.3
Nonprocesses	11.6	10.0	1.6	8.4	2.6
Quarrying, Sand/Gravel	8.5	4.1	0.6	3.5	1.0
Asphalt Dryers	7.2	6.8	0.6	6.2	0.6
Incinerators	0.5	0.3	0.3	0	0.6
TOTAL	53.3	44.5	26.3	18.2	45.6
AREA SOURCES					
Agricultural Burning	3.8	3.8	0	3.8	0
Open Burning	16.9	16.9	0	16.9	0
Paved Roads	19.9	19.9	19.9	0	35.8
Unpaved Roads	5.2	5.2	5.2	0	4.3
Other Sources	9.6	9.6	9.6	0	17.3
TOTAL	55.4	55.4	34.7	20.7	57.4
GRAND TOTAL	108.7	99.9	61.0	38.9	103.0

*See Table II-4 and Figure II-1 for municipalities included.

TABLE II-8

SOURCE CATEGORY CONTRIBUTIONS TO THE EMISSION INVENTORY FOR THE SOUTHERN STUDY AREA*

POINT SOURCES (Over 10 tons/year)	CONTRIBUTIONS TONS/DAY				
	BASE	COMPLIANCE	STRATEGY	REDUCTION	1990
Oil Fired Boilers	26.8	19.2	19.2	0	35.2
Bagasse Fired Boilers	15.8	3.1	2.7	0.4	2.7
Stationary Engines	2.1	2.1	2.1	0	3.9
Processes	3.5	2.3	2.3	0	3.7
Nonprocesses	9.5	9.0	0.7	8.3	1.3
Quarrying, Sand/Gravel	8.9	2.7	0.2	2.5	0.3
Asphalt Dryers	3.0	2.2	2.1	0.1	2.1
Incinerators	0.4	0.2	0.2	0	0.4
TOTAL	70.0	40.8	29.5	11.3	49.6
AREA SOURCES					
Agricultural Burning	12.4	12.4	0	12.4	0
Open Burning	5.4	5.4	0	5.4	0
Paved Roads	18.0	18.0	18.0	0	32.4
Unpaved Roads	37.0	37.0	37.0	0	30.3
Other Sources	3.9	3.9	3.9	0	7.0
TOTAL	76.7	76.7	58.9	17.8	69.7
GRAND TOTAL	146.7	117.5	38.4	29.1	119.4

*See Table II-5 and Figure II-2 for municipalities included.

TABLE II-9

SOURCE CATEGORY CONTRIBUTIONS
TO THE EMISSION INVENTORY
FOR THE NORTHWESTERN STUDY AREA*

POINT SOURCES (Over 10 tons/year)	CONTRIBUTIONS TONS/DAY				
	BASE	COMPLIANCE	STRATEGY	REDUCTION	1990
Oil Fired Boilers	0.6	0.6	0.6	0	1.0
Bagasse Fired Boilers	8.0	1.5	1.3	0.2	1.3
Stationary Engines	0	0	0	0	0
Processes	0	0	0	0	0
Nonprocesses	2.7	2.7	0.1	2.6	0.1
Quarrying, Sand/Gravel	2.3	0.8	0.1	0.7	0.1
Asphalt Dryers	0.4	0.4	0.2	0.2	0.2
Incinerators	0	0	0	0	0
TOTAL	14.0	5.6	2.1	3.5	2.5
AREA SOURCES					
Agricultural Burning	9.0	9.0	0	9.0	0
Open Burning	4.9	4.9	0	4.9	0
Paved Roads	10.4	10.4	10.4	0	18.7
Unpaved Roads	4.0	4.0	4.0	0	3.2
Other Sources	8.9	8.9	8.9	0	16.5
TOTAL	37.2	37.2	23.3	13.9	38.0
GRAND TOTAL	51.2	42.8	25.4	17.4	40.5

*See Table II-6 and Figure II-3 for municipalities included.

CHAPTER III

MODEL VALIDATION

To establish the validity of the dispersion model, source-receptor relationships were developed for 11 monitoring stations where 1976 monitoring data were available. Seven stations were located in the northeast quarter of the island, in the San Juan metropolitan area. Four stations were located in the southern study area near Ponce. After the emission inventories had been prepared for each section of the island, concentrations were predicted for the 11 stations using the dispersion model, and then compared to the measured values.

Table III-1 presents this comparison in a tabular format, while Figure III-1 presents the comparison graphically. A linear regression analysis of the data yields a slope of 0.9 with an intercept of 23. The coefficient of determination was 0.6. Because of the limited number of observations, ES chose to use a slope of 1.0 and an intercept of 20. This line is shown on the graph. Basically, this means that to any value that the dispersion model predicts, 20 should be added. The difference of 20 $\mu g/m^3$ between measured and predicted is typical for TSP dispersion analyses, and is probably due to the influence of fugitive dust, which is not entirely accounted for in the emission inventory.

For the protection of health and welfare, the Federal government has established sets of air quality standards for TSP and other pollutants. TSP air quality standards established by the Puerto Rico Environmental Quality Board are identical and appear below:

1.	Annual Average -	Primary	75 $\mu g/m^3$
		- Secondary	60 $\mu g/m^3$
2.	24-Hour Average -	Primary	260 $\mu g/m^3$
		- Secondary	150 $\mu g/m^3$

The 1976 measured air quality in Puerto Rico exceeded both the annual primary and secondary standards, as indicated in Table III-1.

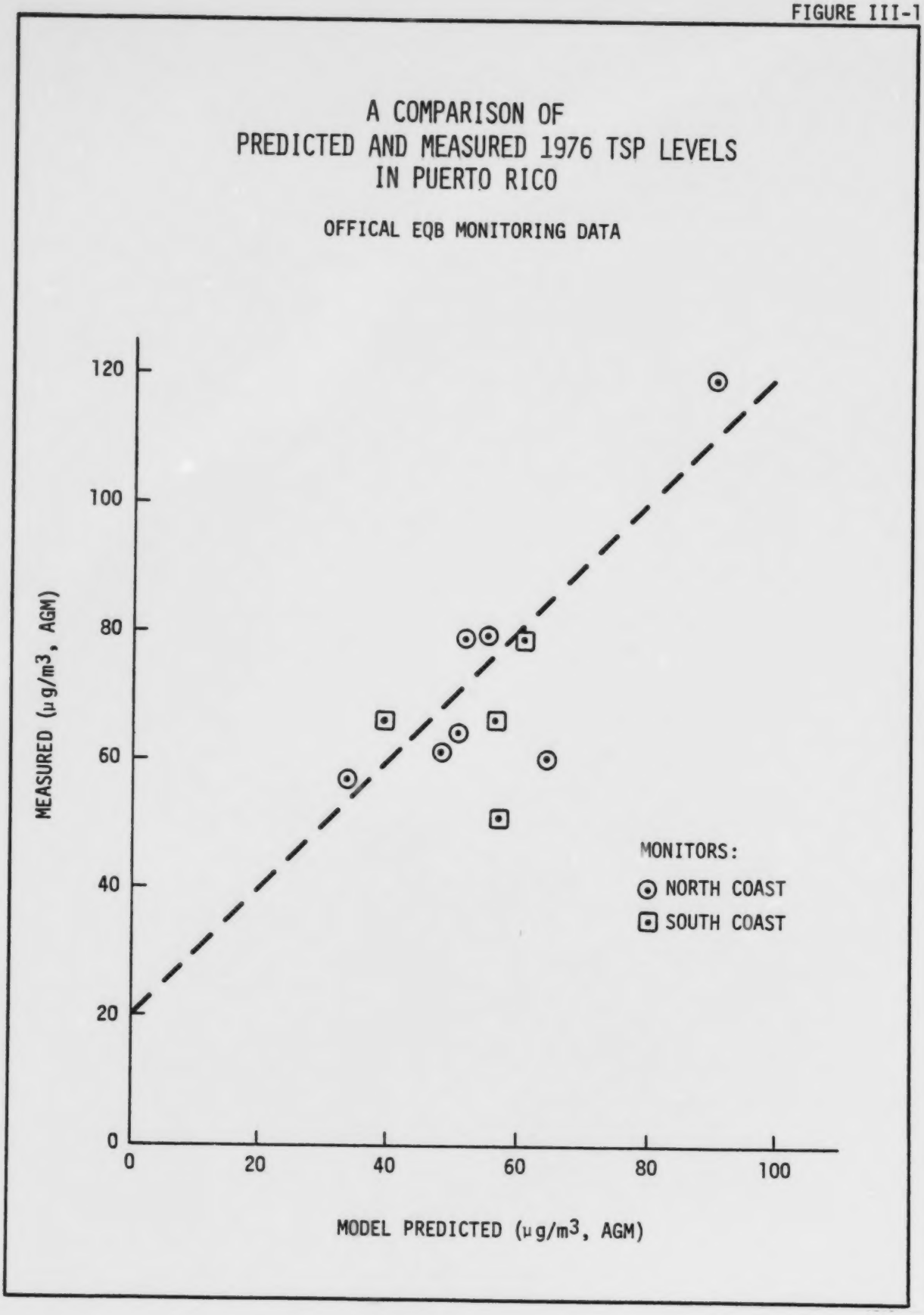
TABLE III-1

A COMPARISON OF PREDICTED AND
MEASURED TSP LEVELS IN PUERTO RICO
OFFICIAL EQB MONITORING DATA

STATION	UTM		ANNUAL GEOMETRIC MEAN ($\mu g/m^3$)	
	EAST	NORTH	PREDICTED[a]	MEASURED
North Coast Monitors:				
San Juan	192.1	64.7	33	57
Bayamon	179.9	63.2	64	60
Catano, Port Zone	186.6	66.1	52	78
Catano, Las Vegas	183.0	66.0	55	79
Guaynabo, USGS	186.0	65.7	51	64
Guaynabo, Pump House	186.0	66.5	90	119
Toa Baja	178.7	66.0	48	61
South Coast Monitors:				
Ponce	134.5	20.0	60	78
Guayanilla, Plaza	116.6	19.4	57	66
Guayanilla, Magas Arriba	117.1	20.7	57	51
Penuelas	121.9	24.6	38	67

[a] Using the uncalibrated model.

FIGURE III-1


A COMPARISON OF
PREDICTED AND MEASURED 1976 TSP LEVELS
IN PUERTO RICO
OFFICAL EQB MONITORING DATA
MEASURED (µg/m3, AGM)
MODEL PREDICTED (µg/m3, AGM)
0
20
40
60
80
100
120
MONITORS:
NORTH COAST
SOUTH COAST

CHAPTER IV

DISCUSSION OF RESULTS

Emission and meteorological data files were developed for three separate geographic areas of Puerto Rico. This approach was justified because the island has distinct characteristics of rugged terrain at its center, affecting dispersion, and because meteorological data were available from three locations. In previous reports published by ES, an analysis of the variations in meteorological data between the San Juan, Ponce, and Ramey was made. Specific data concerning emissions have been discussed in Chapter II.

EPA's air quality display model (AQDM) was used to predict ambient TSP concentrations over the entire island of Puerto Rico. In general, a four-by-four kilometer (km) grid spacing was used for receptor locations in the analysis. Further detail was obtained in the San Juan and Ponce industrial areas by using a grid spacing of two-by-two km.

Concentration isopleths were developed for the four scenarios analyzed:

- Existing base conditions for 1976 - All point and area sources operating at 1976 production levels.
- Compliance emissions - The 1976 operating conditions were still maintained but emissions were reduced in order to comply with existing EQB regulations.
- Control strategies - Six specific control strategies were developed and analyzed for their combined effect in reducing ambient air quality levels.
- Projections to 1990 - Base year strategy emissions were projected to 1990 using growth data supplied by industry and governmental agencies. (All growth was assumed to occur in place.)

Figures IV-1 through IV-4 illustrate the total suspended particulate concentration levels for the entire island. Existing levels of TSP are shown in Figure IV-1. Figure IV-2 illustrates the concentration isopleths after all sources comply with existing EQB regulations. Figure IV-3 illustrates the concentrations after implementation of all control strategies. Figure IV-4 presents the concentrations expected in the projection year 1990.

It should be pointed out that these concentrations are annual arithmetic mean (AAM) values, because the AQDM does not have the capability of predicting the annual geometric mean (AGM) concentrations needed for comparison with TSP standards. EPA has developed a technique to estimate the annual geometric mean based on annual arithmetic mean concentrations and the standard geometric deviation (SGD). Engineering-Science used the SGD data from monitoring reports to convert the AAM concentrations predicted for the monitoring sites to AGM predictions. These latter values were then compared in Chapter III to measured data, and the EQB and Federal ambient air quality standards, which are expressed in terms of the annual geometric mean.

Centers of industrial activity on the island were obviously coincident with high TSP concentrations. In general, these were the San Juan, Ponce, Guanica and Yabucoa areas. Other regions of the island showed somewhat less emissions activity and lower TSP levels.

The south coast of the island is arid. Emissions from area sources and other nontraditional point sources are extremely high in this geographic area. Substantial amounts of emissions occur as a result of dust reentrainment from paved roads, as well as dust generated from unpaved roads. Special emission factors for these two categories were developed using the latest EPA methodology. The results on the south coast of the island indicated that primary ambient air quality standards were exceeded, due in part to the influence of dust reentrainment. The results for the north coast of the island also indicated that standards were exceeded, but a contribution analysis shows that industrial point sources were more responsible.

Several areas near San Juan and Ponce had been formally declared in the Federal Register as not attaining TSP standards on the basis of monitoring data. The computer-modeled results of ES support the declaration of these areas as nonattainment.

Although the model is limited in terms of accuracy for predicting absolute concentrations of pollutants at a certain receptor due to input parameter constraints, it is reliable in showing area-wide concentrations and relative effects of emission changes.

For 1990, concentrations exceeding primary and secondary standards are predicted by the model. Several factors caused the appearance of these high concentrations:

1. All growth was assumed to occur in place. EQB estimates of the growth factors at some types of plants were almost 2 for the 15-year period. Some of the anticipated growth is expected to occur at other scattered greenfield locations through the construction of new plants, rather than because of expansion at existing facilities.

2. The background concentration, due in part to process fugitive losses, was assumed to remain constant at 20 $\mu g/m^3$ through 1990. Some reduction in fugitive losses may occur or be required in the future, and the contribution to the total concentration would be reduced.

3. Predicted concentrations at several receptors were high due to their close proximity to sources with low stack heights.

Because of these considerations, the predicted 1990 concentrations are probably "worst-case" estimates. Actual 1990 concentrations will be somewhat lower.

SOURCE CATEGORY CONTRIBUTIONS TO PREDICTED AIR QUALITY LEVELS

The relative importance of major emission source categories to ambient air quality levels was calculated for the 11 monitoring stations used in the AQDM calibration/validation. These data are summarized in Tables IV-1 through IV-11 and on corresponding bar charts in Figures IV-5 through IV-15. In each case, the base, compliance, strategy, and 1990 values for ambient air quality have been tabulated. The tables show the importance of point and area source emission categories and their subsequent impact on ambient air quality levels.

CATANO NONATTAINMENT STUDY AREA

Model results of the Catano nonattainment study area showed that base year air quality levels exceeded ambient standards, both for the annual and 24-hour averaging periods. Figure IV-1 shows the concentration isopleths for the baseyear 1976. For the compliance scenario, predicted ambient air quality levels still exceeded the 75 $\mu g/m^3$ primary ambient air quality standard. For the control strategies tested, predicted air quality levels in the Catano area were below EQB and Federal standards. In this case, a 50 $\mu g/m^3$ improvement in air quality helped to attain the secondary standard. Figure IV-3 illustrates these results.

The 1990 projected air quality levels for the Catano study area resulted in concentrations over the primary standard. This high concentration was largely due to the grain mills located near the Guaynabo station. Although the facility is well controlled, the production rate of this source was assumed to double. Considering the physical limitation of this source, it is doubtful whether production could double by 1990. In order to meet that kind of production level, a new plant at a different location would have to be built.

Based on these considerations, ES does not feel that additional strategies will be needed to maintain standards through 1990 for this area.[1]

As a result of the predominant easterly winds on the island, the air quality levels in Dorado were due to emissions that occurred in the more industrialized areas of the San Juan metropolitan area. Predicted base year levels in Dorado were close to the secondary ambient air quality standard. However, for the compliance case, emissions were expected to be substantially reduced, with air quality levels well within the standards. Implementing all of the control strategies described earlier would result in a further improvement in air quality here. For the projections to 1990, concentrations would increase to about 51 $\mu g/m^3$. In all cases studied, the primary and secondary ambient air quality standards were attained and maintained for the Dorado area.

GUAYANILLA-PENUELAS NONATTAINMENT STUDY AREA

Air quality in the Guayanilla-Penuelas area was substantially affected by the emissions that occurred in Ponce. In addition, major point sources along the coast contribute to the air quality levels for this particular area. The highest annual concentrations for the base year were about 90 $\mu g/m^3$. Concentrations decreased by 15 $\mu g/m^3$ as a result of complying with the existing emissions regulations. Another 13 $\mu g/m^3$

[1] If the emission did not increase (a no growth situation) for the grain mills, the model-predicted 1990 air quality level would be about 10-15 $\mu g/m^3$ lower.

improvement was noted for the control strategy scenario. When the emissions are projected through 1990, ambient air quality levels increase to about 71 $\mu g/m^3$. In all cases, the primary ambient air quality standard will be maintained in the Guayanilla-Penuelas study area.

Emissions from area sources in Guayanilla-Penuelas were distinctly higher than those in other parts of the island. This was due to the generally arid climate that exists in this area. Good correlation was found with the model predicted and measured ambient air quality levels in this area. Substantial improvements in this part of the island could be obtained from controlling dust on paved and unpaved roads. In Guayanilla-Penuelas it is recommended that the area source emissions be investigated further to see if a more cost-effective program to reduce particulate emissions and improve air quality levels could be established there.

Predominant wind patterns on the island are from the east. In the Ponce area, the winds are primarily from the southwest and northeast and show a distinct diurnal variation. As a result, predicted high concentrations are expected to occur in the Caribbean Sea, just off the coast of Ponce. Since the monitoring data did not verify the computer predicted values, the municipality of Ponce was designated as an unclassified area by EQB and EPA. The area will likely undergo further study by EQB to more accurately estimate TSP levels for this portion of the island. The highest concentration overland for the base year was about 97 $\mu g/m^3$ annual arithmetic mean. For the compliance scenario, ambient air quality levels improved about 16 $\mu g/m^3$. Substantial reductions were noted when several control strategies were tested. In this case, 16 $\mu g/m^3$ improvement was observed. The projections to 1990 showed that air quality levels would increase from the strategy scenario by about 12 $\mu g/m^3$. Concentrations exceeding the secondary standard and approaching the primary standard were predicted for a small area on the southern coast near Ponce in 1990. Factors leading to the high concentrations are mentioned in the discussion for the Catano study area.

MAINTENANCE AREAS

Using the same strategies and growth data as in the nonattainment areas, air quality levels for each of the maintenance areas were predicted to be below Commonwealth and Federal primary standards. The maximum 1990 value for any of the maintenance areas was about 70 $\mu g/m^3$ AGM near Yabucoa.

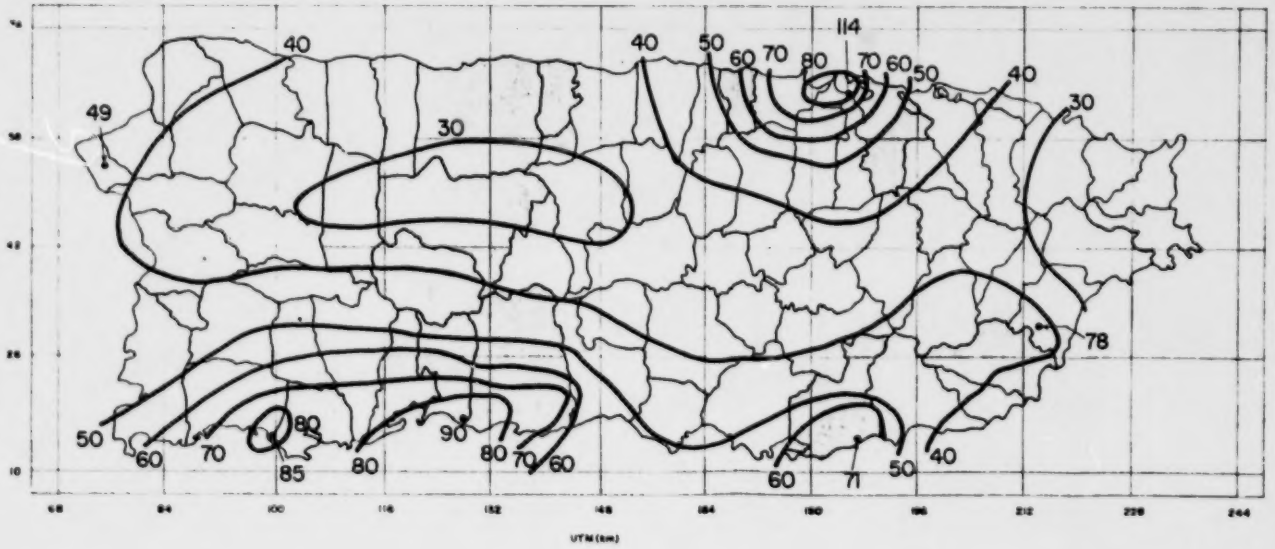
Figures IV-1 through IV-4 show the concentration patterns for all areas of the island, including the 10 maintenance municipalities studied by ES.

From the analysis conducted by ES, all designated maintenance areas on the island will be able to maintain air quality levels which are below Commonwealth and Federal limits, assuming the rapid growth used in this study. Some areas on the island should be dedesignated as maintenance areas since the projected 1990 air quality levels are far below the primary TSP standard of 75 $\mu g/m^3$. ES suggests that the following maintenance areas be dedesignated:

Maintenance Area	Air Quality Level ($\mu g/m^3$ AGM)	
	Base Case 1976	1990
Dorado	60	49
Mayaguez	39	39
Caguas	41	29
Lares-Utuado-Adjuntas	39	34
Aguadilla	44	41
Arecibo-Barceloneta	29	29

In the analysis of the areas identified above, ES assumed that the strategies developed for the nonattainment areas would also apply to the maintenance areas. Even though there does not appear to be much of a change from the base 1976 air quality levels to the 1990 levels for some municipalities, emissions and ambient concentrations will decrease because of the strategies and then increase as a result of the anticipated growth. For example, the 1976 air quality level in Mayaguez of 39 $\mu g/m^3$ will be reduced to 29 because of the strategies, then increase by 10 to 39 because of growth.

PUERTO RICO ATTAINMENT ANALYSIS ALL POINT AND AREA SOURCES
TSP - ($\mu g/m^3$) ANNUAL ARITHMETIC MEAN
BASEYEAR CONDITIONS



PUERTO RICO ATTAINMENT ANALYSIS ALL POINT AND AREA SOURCES
TSP - (ug/m3) ANNUAL ARITHMETIC MEAN
ASSUMING COMPLIANCE WITH EXISTING REGULATIONS

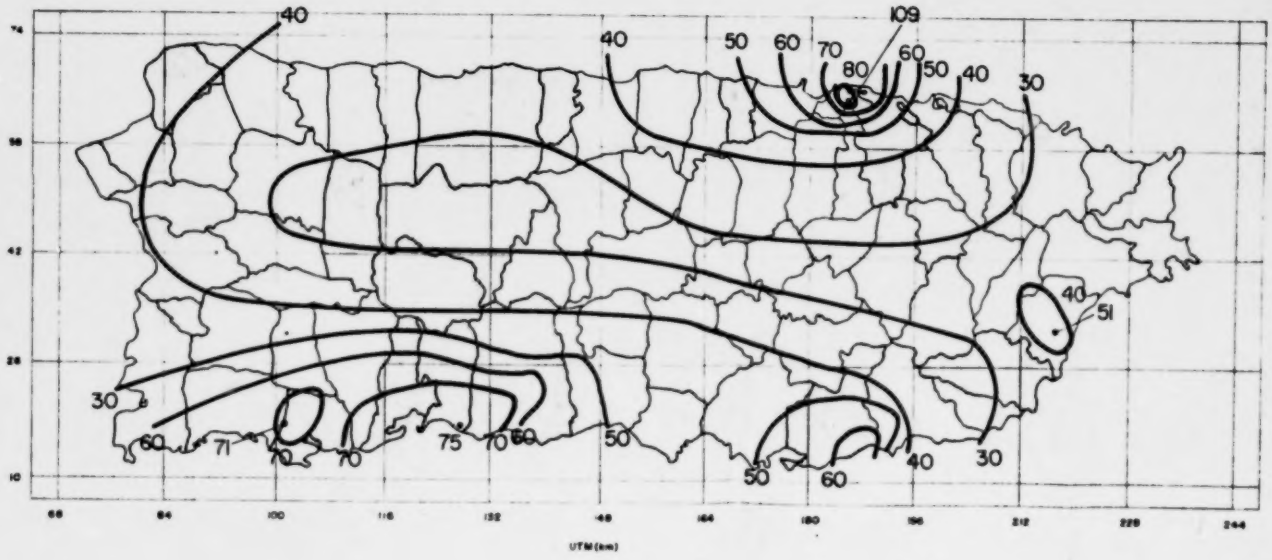


FIGURE IV-3

PUERTO RICO ATTAINMENT ANALYSIS ALL POINT AND AREA SOURCES
TSP - ($\mu g/m^3$) ANNUAL ARITHMETIC MEAN
IMPLEMENTATION OF ALL CONTROL STRATEGIES

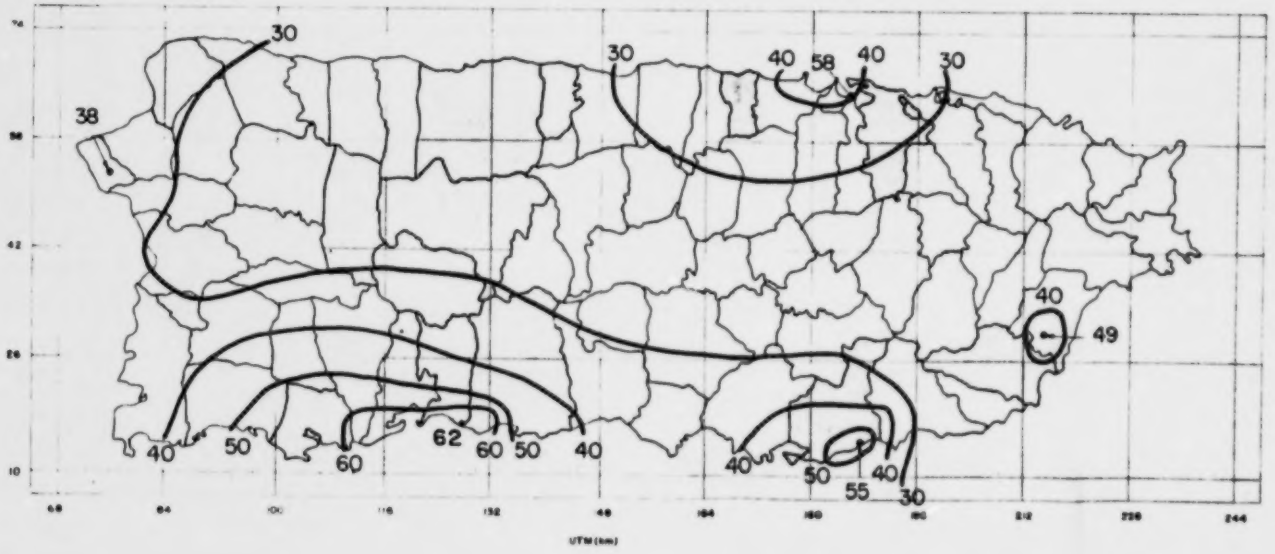


FIGURE IV-4

PUERTO RICO ATTAINMENT ANALYSIS ALL POINT AND AREA SOURCES
TSP - ($\mu g/m^3$) ANNUAL ARITHMETIC MEAN
PROJECTIONS TO 1990

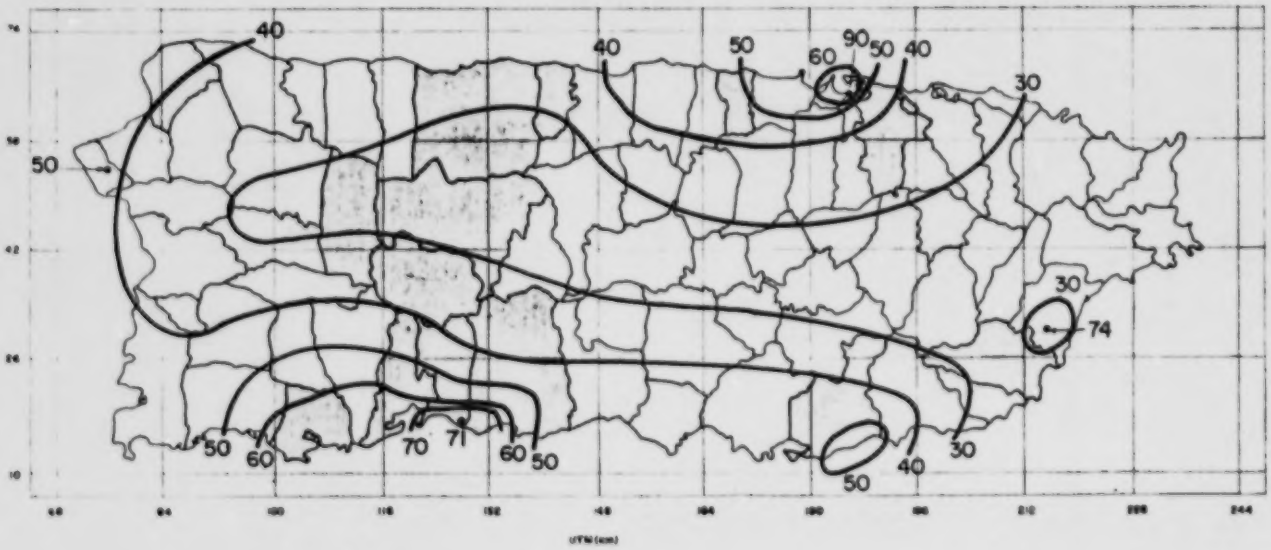


TABLE IV-1

SOURCE CATEGORY CONTRIBUTIONS TO

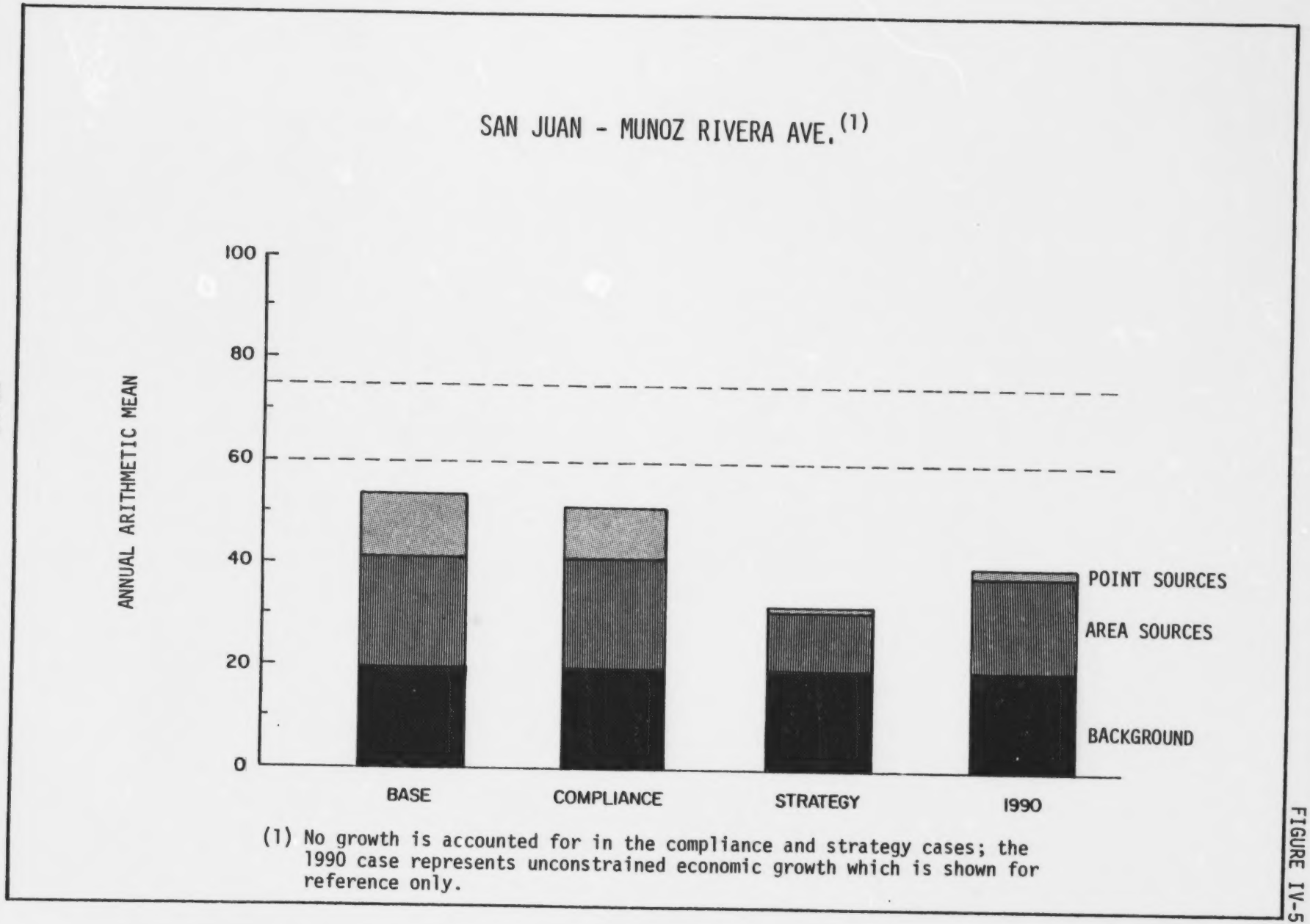
PREDICTED AIR QUALITY

PREDICTION SITE: SAN JUAN, MUNOZ RIVERA

SAROAD IDENT: 40-2160-001-F01 1976 AGM: 56

LOCATION: 192.1 64.7

	CONTRIBUTIONS $\mu g/m^3$ - AAM				
POINT SOURCES	BASE	COMPLIANCE	STRATEGY	REDUCTION	1990
Oil Fired Boilers	0.2	0.2	0.2	0	0.3
Bagasse Fired Boilers	0	0	0	0	0
Stationary Engines	0	0	0	0	0
Processes	0.1	0	0	0	0.1
Nonprocesses	3.1	2.8	0.3	2.5	0.4
Quarrying, Sand/Gravel	3.3	1.3	0.5	0.8	0.8
Asphalt Dryers	5.4	5.4	0.3	5.1	0.3
Incinerators	0.1	0.1	0.1	0	0.2
TOTAL	12.2	9.8	1.4	8.4	2.1
AREA SOURCES					
Agricultural Burning	0.9	0.9	0	0.9	0
Open Burning	10.2	10.2	0	10.2	0
Paved Roads	6.1	6.1	6.1	0	11.0
Unpaved Roads	1.9	1.9	1.9	0	1.6
Other Sources	2.9	2.9	2.9	0	5.2
TOTAL	22.0	22.0	10.9	11.1	17.8
GRAND TOTAL	34.2	31.8	12.3	19.5	19.9
Corrected Annual Geometric Mean	33	31	12	-	19



(1) No growth is accounted for in the compliance and strategy cases; the 1990 case represents unconstrained economic growth which is shown for reference only.

FIGURE IV-5

TABLE IV-2

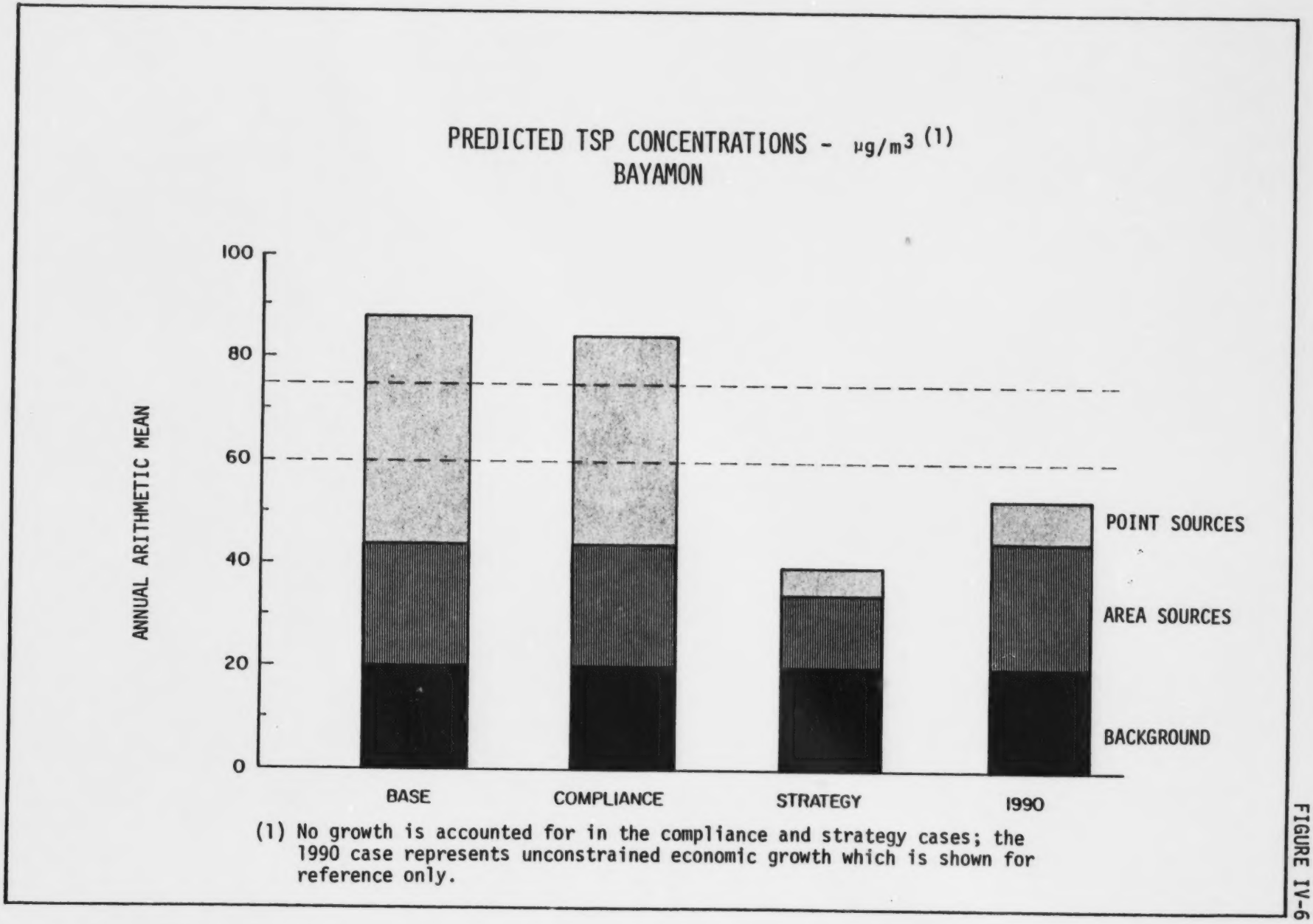
SOURCE CATEGORY CONTRIBUTIONS TO
PREDICTED AIR QUALITY

PREDICTION SITE: BAYAMON

SAROAD IDENT: 40-0380-001-F01 Measured 1976 AGM: 60 $\mu g/m^3$

LOCATION: 179.9 63.2

	CONTRIBUTIONS $\mu g/m^3$ - AAM				
POINT SOURCES	BASE	COMPLIANCE	STRATEGY	REDUCTION	1990
Oil Fired Boilers	3.4	2.4	2.4	0	4.3
Bagasse Fired Boilers	0	0	0	0	0
Stationary Engines	0.1	0.1	0.1	0	0.1
Processes	1.3	0.5	0.5	0	0.9
Nonprocesses	27.3	27.0	1.0	26.0	1.6
Quarrying, Sand/Gravel	3.8	1.6	0.3	1.3	0.5
Asphalt Dryers	6.5	6.4	0.3	6.1	0.3
Incinerators	0.1	0.1	0.1	0	0.2
TOTAL	42.5	38.1	4.7	33.4	7.9
AREA SOURCES					
Agricultural Burning	0.7	0.7	0	0.7	0
Open Burning	8.8	8.8	0	8.8	0
Paved Roads	8.0	8.0	8.0	0	14.4
Unpaved Roads	1.7	1.7	1.7	0	1.4
Other Sources	4.5	4.5	4.5	0	8.1
TOTAL	23.7	23.7	14.2	9.5	23.9
GRAND TOTAL	66.2	61.8	18.9	42.9	31.8
Corrected Annual Geometric Mean	64	66	18	-	31



(1) No growth is accounted for in the compliance and strategy cases; the 1990 case represents unconstrained economic growth which is shown for reference only.

FIGURE IV-6

TABLE IV-3

SOURCE CATEGORY CONTRIBUTIONS TO

PREDICTED AIR QUALITY

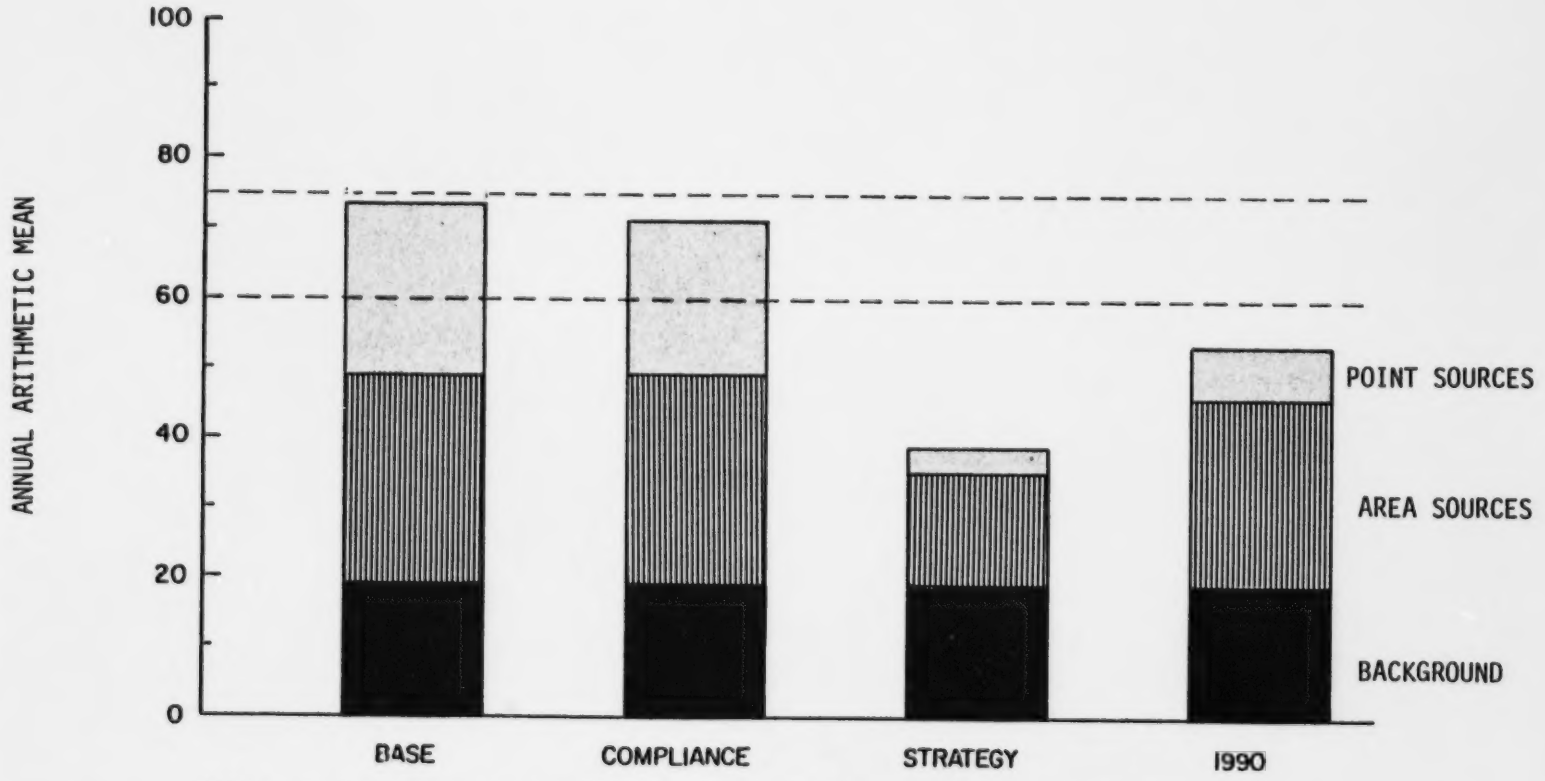
PREDICTION SITE: CATANO, PORT ZONE

SAROAD IDENT: 40-2160-001-F01 Measured 1976 AGM: 80 $\mu g/m^3$

LOCATION: 186.6 66.1

	CONTRIBUTIONS $\mu g/m^3$ - AAM				
POINT SOURCES	BASE	COMPLIANCE	STRATEGY	REDUCTION	1990
Oil Fired Boilers	0.8	0.5	0.5	0	1.0
Bagasse Fired Boilers	0	0	0	0	0
Stationary Engines	0	0	0	0	0
Processes	0.4	0.2	0.2	0	0.3
Nonprocesses	11.0	10.7	1.5	9.2	2.6
Quarrying, Sand/Gravel	3.8	1.5	0.3	1.2	0.6
Asphalt Dryers	8.6	8.6	0.5	8.1	0.5
Incinerators	0.5	0.5	0.5	0	0.9
TOTAL	25.1	22.0	3.5	18.5	5.9
AREA SOURCES					
Agricultural Burning	0.8	0.8	0	0.8	0
Open Burning	12.6	12.6	0	12.6	0
Paved Roads	7.5	7.5	7.5	0	13.5
Unpaved Roads	1.7	1.7	1.7	0	1.4
Other Sources	6.1	6.1	6.1	0	11.0
TOTAL	28.7	28.7	15.3	13.4	25.9
GRAND TOTAL	53.8	50.7	18.8	31.9	31.8
Corrected Annual Geometric Mean	52	49	18	-	31

PREDICTED TSP CONCENTRATIONS - $\mu g/m^3$ (1)
CATANO



(1) No growth is accounted for in the compliance and strategy cases; the 1990 case represents unconstrained economic growth which is shown for reference only.

FIGURE IV-7

TABLE IV-4

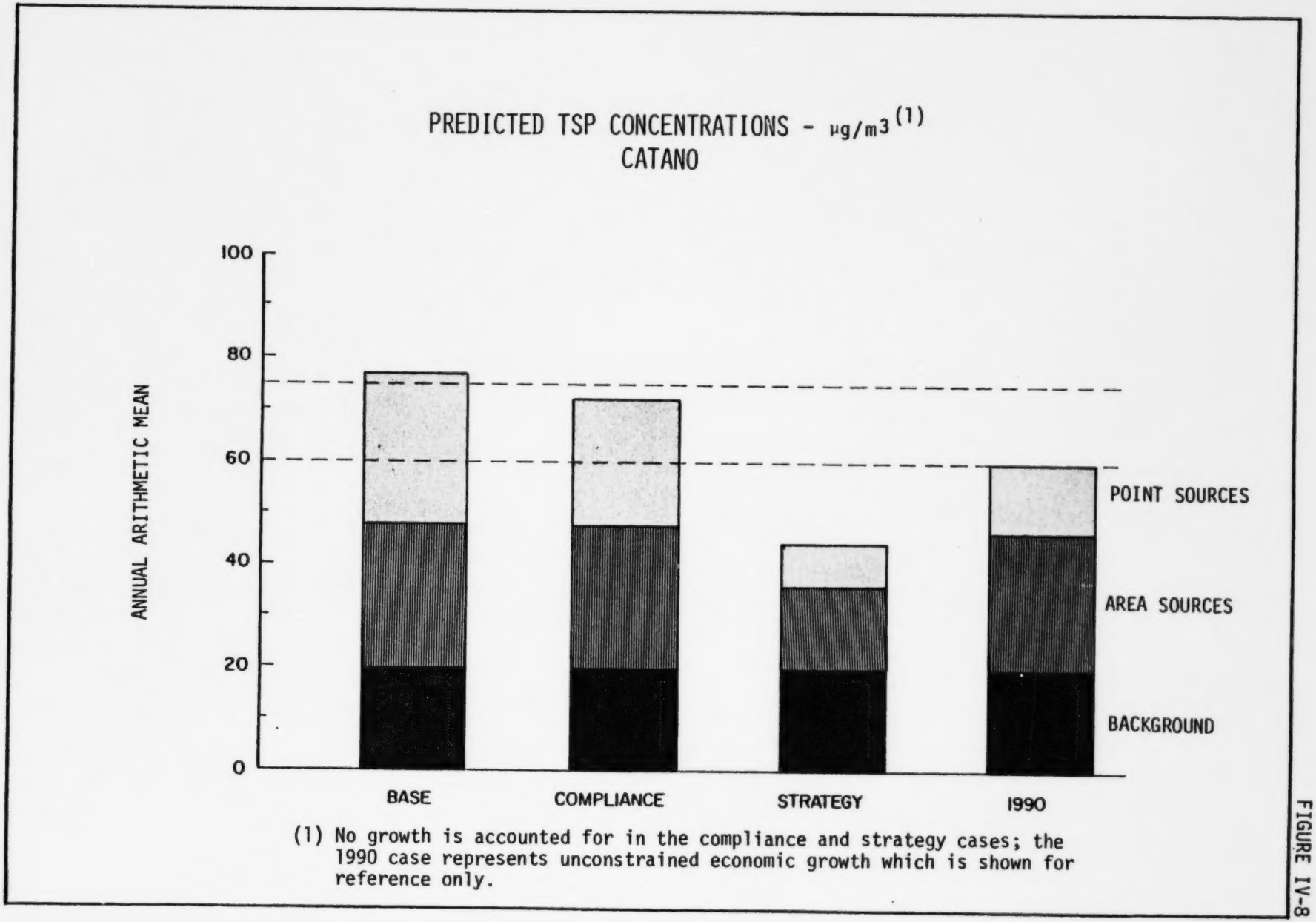
SOURCE CATEGORY CONTRIBUTIONS TO
PREDICTED AIR QUALITY

PREDICTION SITE: CATANO, LAS VEGAS

SAROAD IDENT: 40-0560-004-F01 Measured 1976 AGM: 79 $\mu g/m^3$

LOCATION: 183.0 66.0

	CONTRIBUTIONS $\mu g/m^3$ - AAM				
POINT SOURCES	BASE	COMPLIANCE	STRATEGY	REDUCTION	1990
Oil Fired Boilers	4.5	2.9	2.9	0	5.3
Bagasse Fired Boilers	0	0	0	0	0
Stationary Engines	0.1	0.1	0.1	0	0.2
Processes	3.5	1.4	1.4	0	2.7
Nonprocesses	10.4	10.1	2.4	7.7	4.4
Quarrying, Sand/Gravel	3.8	1.6	0.3	1.3	0.6
Asphalt Dryers	7.2	7.2	0.4	6.8	0.4
Incinerators	0.2	0.2	0.2	0	0.4
TOTAL	29.7	23.5	7.7	15.8	14.0
AREA SOURCES					
Agricultural Burning	0.8	0.8	0	0.8	0
Open Burning	11.3	11.3	0	11.3	0
Paved Roads	7.9	7.9	7.9	0	14.2
Unpaved Roads	1.7	1.7	1.7	0	1.4
Other Sources	5.8	5.8	5.8	0	10.4
TOTAL	27.5	27.5	15.4	12.1	26.0
GRAND TOTAL	57.2	51.0	23.1	27.9	40.0
Corrected Annual Geometric Mean	55	49.0	22 0	-	39



(1) No growth is accounted for in the compliance and strategy cases; the 1990 case represents unconstrained economic growth which is shown for reference only.

FIGURE IV-8

TABLE IV-5

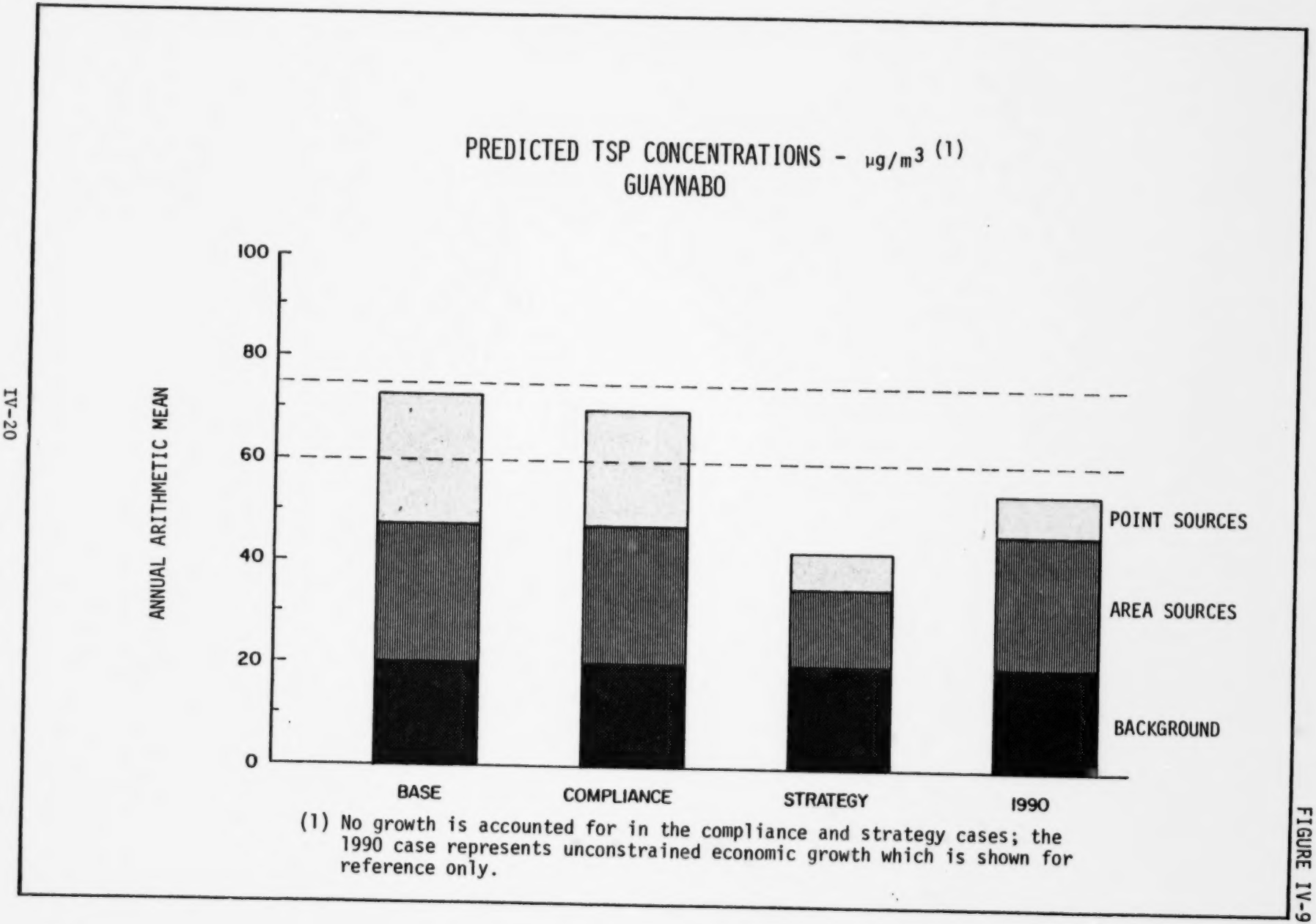
SOURCE CATEGORY CONTRIBUTIONS TO PREDICTED AIR QUALITY

PREDICTION SITE: GUAYNABO, USGS

SAROAD IDENT: 40-1140-001-F01 Measured 1976 AGM: 60 $\mu g/m^3$

LOCATION: 186.0 65.7

	CONTRIBUTIONS $\mu g/m^3$ - AAM				
POINT SOURCES	BASE	COMPLIANCE	STRATEGY	REDUCTION	1990
Oil Fired Boilers	1.9	1.6	1.6	0	2.9
Bagasse Fired Boilers	0	0	0	0	0
Stationary Engines	0	0	0	0	0.1
Processes	0.3	0.2	0.2	0	0.3
Nonprocesses	11.1	10.8	2.6	8.2	5.0
Quarrying, Sand/Gravel	3.8	1.5	0.3	1.2	0.6
Asphalt Dryers	8.9	8.9	0.5	8.4	0.5
Incinerators	0.4	0.4	0.4	0	0.7
TOTAL	26.4	23.4	5.6	17.8	10.1
AREA SOURCES					
Agricultural Burning	0.8	0.8	0	0.8	0
Open Burning	10.9	10.9	0	10.9	0
Paved Roads	7.5	7.5	7.5	0	13.5
Unpaved Roads	1.7	1.7	1.7	0	1.4
Other Sources	5.8	5.8	5.8	0	10.4
TOTAL	26.7	26.7	15.0	11.7	25.3
GRAND TOTAL	53.1	50.1	20.6	29.5	35.4
Corrected Annual Geometric Mean	51	48	20	-	34



(1) No growth is accounted for in the compliance and strategy cases; the 1990 case represents unconstrained economic growth which is shown for reference only.

FIGURE IV-9

TABLE IV-6

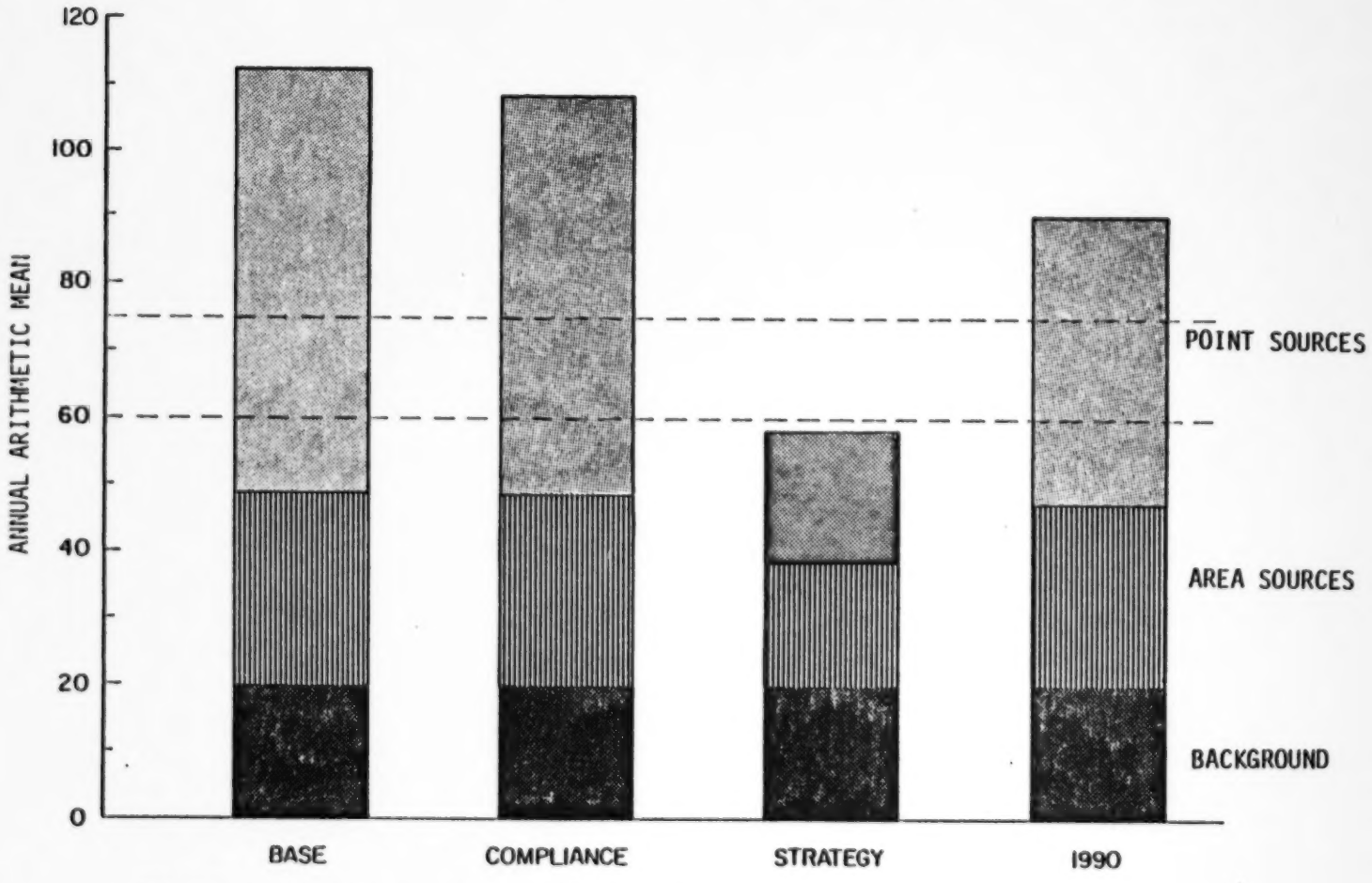
SOURCE CATEGORY CONTRIBUTIONS TO PREDICTED AIR QUALITY

PREDICTION SITE: GUAYNABO, PUMP HOUSE

SAROAD IDENT: 40-1140-002-F01 1976 AGM: 119

LOCATION: 186.0 66.5

	CONTRIBUTIONS $\mu g/m^3$ - AAM				
POINT SOURCES	BASE	COMPLIANCE	STRATEGY	REDUCTION	1990
Oil Fired Boilers	1.0	0.8	0.8	0	1.3
Bagasse Fired Boilers	0	0	0	0	0
Stationary Engines	0	0	0	0	0
Processes	1.2	0.3	0.3	0	0.7
Nonprocesses	49.3	49.0	20.4	28.6	39.4
Quarrying, Sand/Gravel	3.7	1.5	0.3	1.2	0.6
Asphalt Dryers	8.0	8.0	0.4	7.6	0.4
Incinerators	0.4	0.4	0.4	0	0.7
TOTAL	63.6	60.0	22.6	37.4	43.1
AREA SOURCES					
Agricultural Burning	0.8	0.8	0	0.8	0
Open Burning	12.5	12.5	0	12.5	0
Paved Roads	7.7	7.7	7.7	0	13.9
Unpaved Roads	1.7	1.7	1.7	0	1.3
Other Sources	6.5	6.5	6.5	0	11.7
TOTAL	29.2	29.2	15.9	13.3	26.9
GRAND TOTAL	92.8	89.2	38.5	50.7	70.0
Corrected Annual Geometric Mean	90	86	37	-	67



(1) No growth is accounted for in the compliance and strategy cases; the 1990 case represents unconstrained economic growth which is shown for refererence only.

FIGURE IV-10

TABLE IV-7

SOURCE CATEGORY CONTRIBUTIONS TO PREDICTED AIR QUALITY

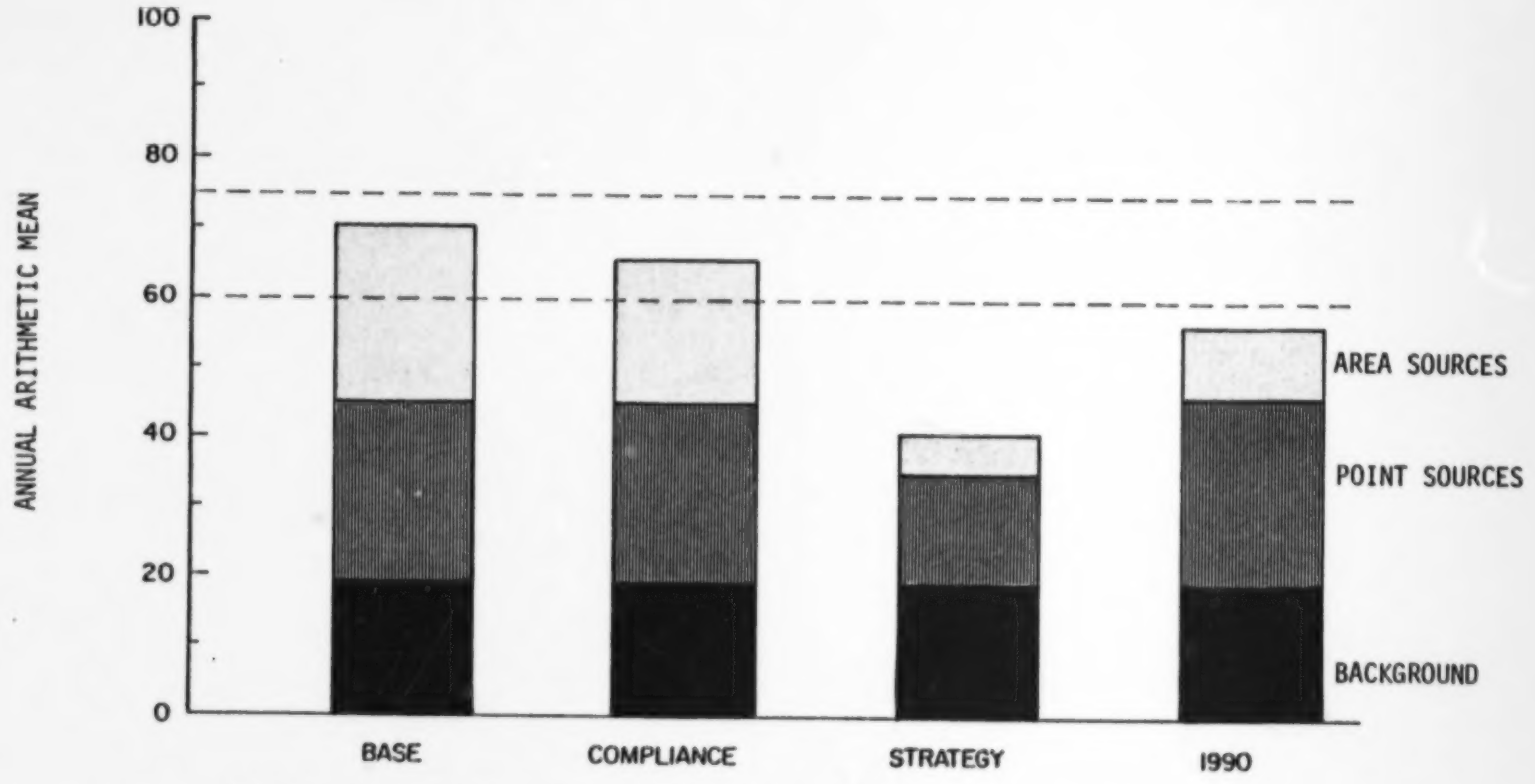
PREDICTION SITE: TOA BAJA

SAROAD IDENT: 40-2065-001-F01 Measured 1976 AGM: 61 $\mu g/m^3$

LOCATION: 178.7 66.0

	CONTRIBUTIONS $\mu g/m^3$ - AAM				
POINT SOURCES	BASE	COMPLIANCE	STRATEGY	REDUCTION	1990
Oil Fired Boilers	4.1	3.3	3.3	0	5.9
Bagasse Fired Boilers	0	0	0	0	0
Stationary Engines	0.1	0.1	0.1	0	0.2
Processes	1.3	0.4	0.4	0	0.8
Nonprocesses	10.5	10.3	1.1	9.2	1.9
Quarrying, Sand/Gravel	3.4	1.5	0.3	1.2	0.4
Asphalt Dryers	5.5	5.5	0.3	5.2	0.3
Incinerators	0.1	0.1	0.1	0	0.2
TOTAL	25.0	21.2	5.6	15.6	9.7
AREA SOURCES					
Agricultural Burning	0.8	0.8	0	0.8	0
Open Burning	8.9	8.9	0	8.9	0
Paved Roads	8.6	8.6	8.6	0	15.5
Unpaved Roads	1.6	1.6	1.6	0	1.3
Other Sources	5.2	5.2	5.2	0	9.4
TOTAL	25.1	25.1	15.4	9.7	26.2
GRAND TOTAL	50.1	46.3	21.0	25.3	35.9
Corrected Annual Geometric Mean	48	45	20	-	35

PREDICTED TSP CONCENTRATIONS - $\mu g/m^3$ (1)
TOA BAJA



(1) No growth is accounted for in the compliance and strategy cases; the 1990 case represents unconstrained economic growth which is shown for reference only.

FIGURE IV-11

TABLE IV-8

SOURCE CATEGORY CONTRIBUTIONS TO

PREDICTED AIR QUALITY

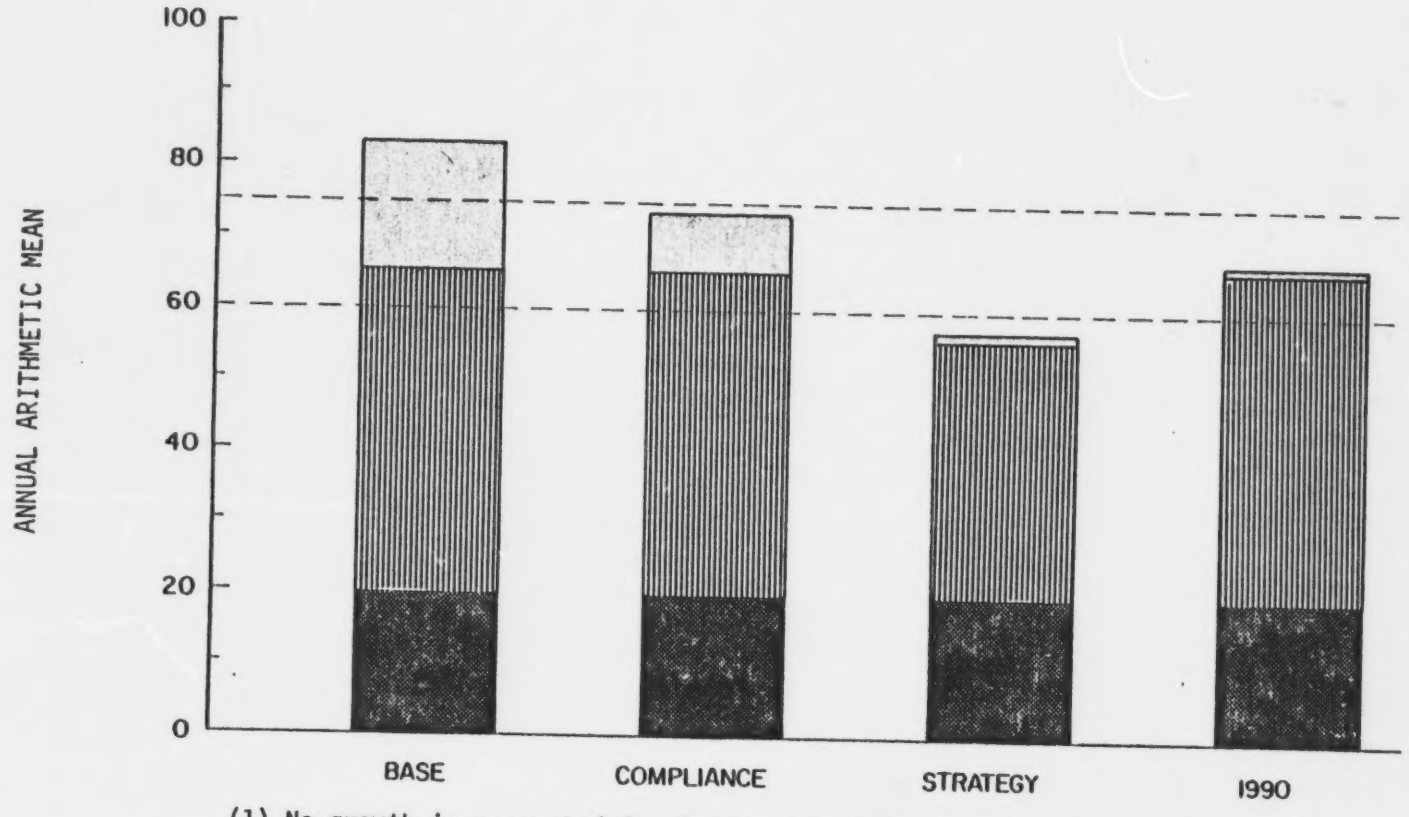
PREDICTION SITE: PONCE

SAROAD IDENT: 40-1920-002-F01 Measured 1976 AGM: 78 $\mu g/m^3$

LOCATION: 134.5 20.0

	CONTRIBUTIONS $\mu g/m^3$ - AAM				
POINT SOURCES	BASE	COMPLIANCE	STRATEGY	REDUCTION	1990
Oil Fired Boilers	0.3	0.3	0.3	0	0.4
Bagasse Fired Boilers	0.1	0	0	0	0
Stationary Engines	0	0	0	0	0
Processes	0	0	0	0	0
Nonprocesses	5.1	4.9	0.2	4.7	0.4
Quarrying, Sand/Gravel	9.9	2.4	0.2	2.2	0.2
Asphalt Dryers	0.4	0.1	0.1	0	0.1
Incinerators	0	0	0	0	0
TOTAL	15.8	7.7	0.8	6.9	1.1
AREA SOURCES					
Agricultural Burning	5.5	5.5	0	5.5	0
Open Burning	3.8	3.8	0	3.8	0
Paved Roads	13.7	13.7	13.7	0	24.7
Unpaved Roads	19.1	19.1	19.1	0	15.7
Other Sources	2.7	2.7	2.7	0	4.9
TOTAL	44.8	44.8	35.5	9.3	45.3
GRAND TOTAL	60.6	52.5	36.3	16.2	46.4
Corrected Annual Geometric Mean	60.0	52.0	36.0	-	46.0

PREDICTED TSP CONCENTRATIONS - $\mu g/m^3$(1)
PONCE



(1) No growth is accounted for in the compliance and strategy cases; the 1990 case represents unconstrained economic growth which is shown for reference only.

FIGURE IV-12

TABLE IV-9

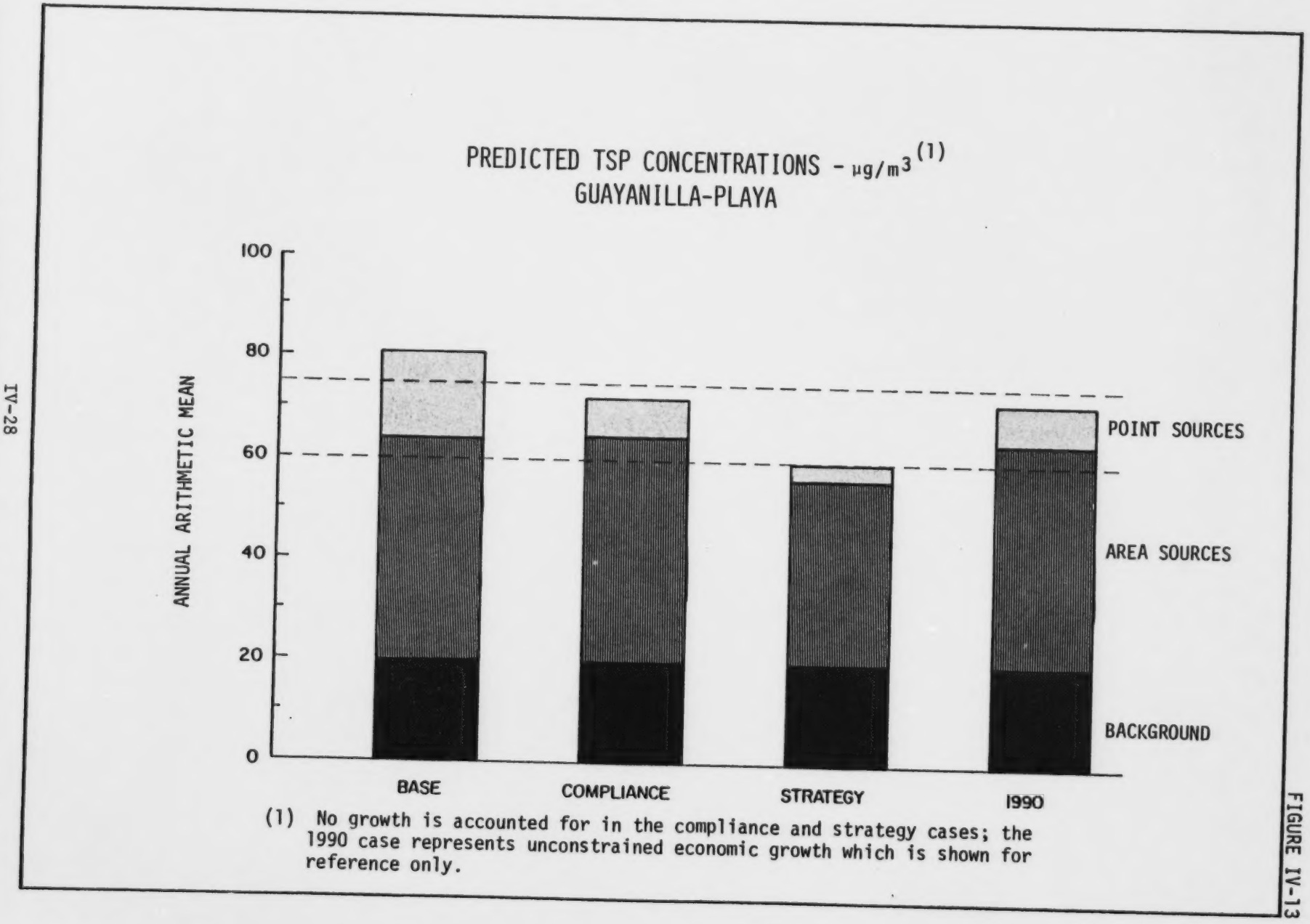
SOURCE CATEGORY CONTRIBUTIONS TO PREDICTED AIR QUALITY

PREDICTION SITE: GUAYANILLA - PLAYA GUAYANILL

SAROAD IDENT: 40-1100-001-F01 Measured 1976 AGM: 66 $\mu g/m^3$

LOCATION: 116.6 19.4

	CONTRIBUTIONS $\mu g/m^3$ - AAM				
POINT SOURCES	BASE	COMPLIANCE	STRATEGY	REDUCTION	1990
Oil Fired Boilers	1.9	1.7	1.7	0	3.0
Bagasse Fired Boilers	0.1	0	0	0	0
Stationary Engines	0.3	0.3	0.3	0	0.5
Processes	1.2	1.1	1.1	0	2.1
Nonprocesses	2.1	2.0	0.2	1.8	0.5
Quarrying, Sand/Gravel	8.5	1.9	0.1	1.8	1.2
Asphalt Dryers	0.1	0	0	0	0
Incinerators	0.1	0	0	0	0
TOTAL	14.3	7.0	3.4	3.6	7.3
AREA SOURCES					
Agricultural Burning	5.3	5.3	0	5.3	0
Open Burning	3.1	3.1	0	3.1	0
Paved Roads	12.0	12.0	12.0	0	21.6
Unpaved Roads	21.0	21.0	21.0	0	17.2
Other Sources	2.5	2.5	2.5	0	4.5
TOTAL	43.9	43.9	35.5	8.4	43.3
GRAND TOTAL	58.2	50.9	38.9	12.0	50.6
Corrected Annual Geometric Mean	57.0	50.0	38.0	-	50.0



(1) No growth is accounted for in the compliance and strategy cases; the 1990 case represents unconstrained economic growth which is shown for reference only.

FIGURE IV-13

TABLE IV-10

SOURCE CATEGORY CONTRIBUTIONS TO PREDICTED AIR QUALITY

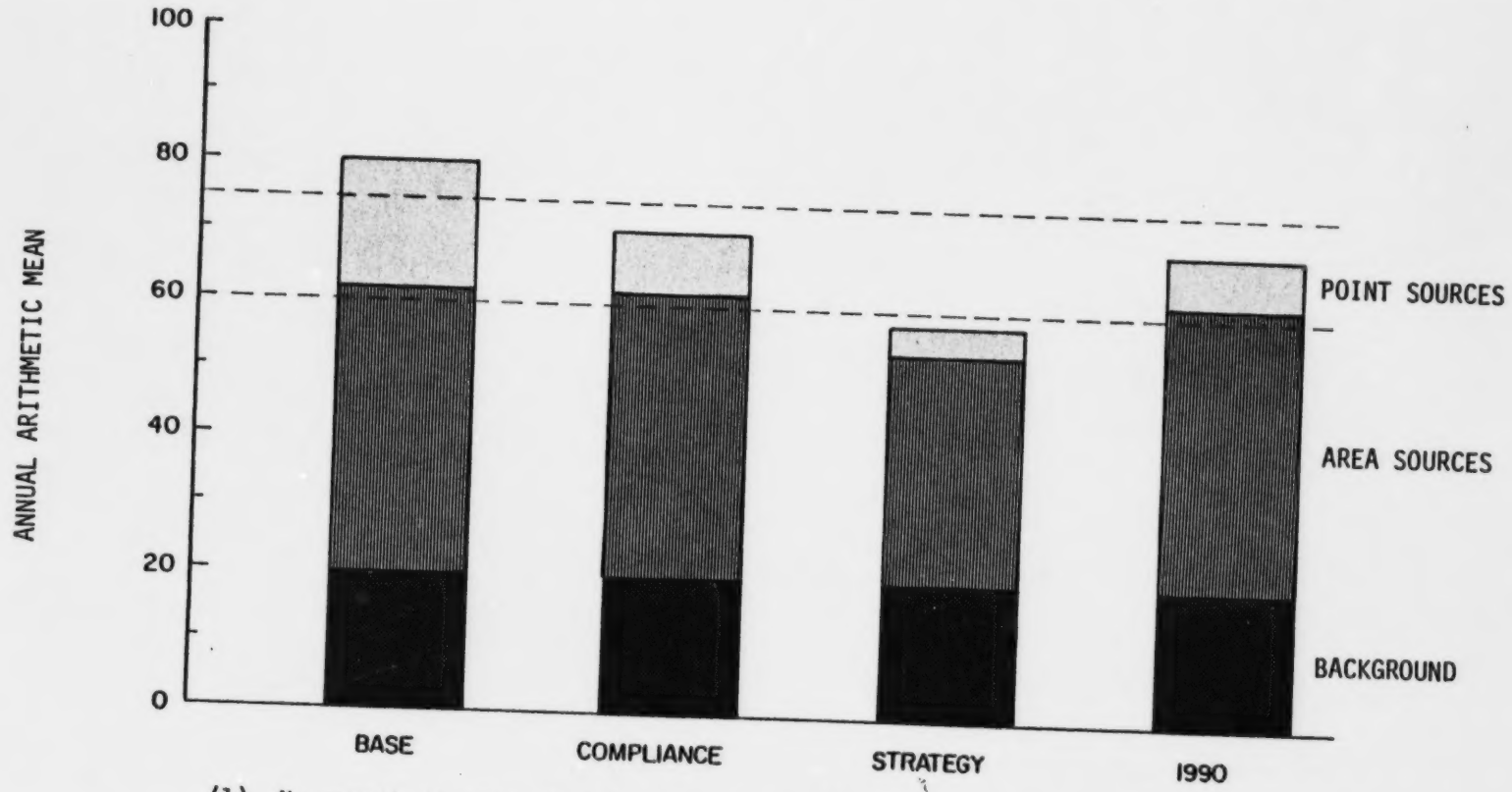
PREDICTION SITE: GUAYANILLA - MAGAS ARRIBA

SAROAD IDENT: 40-1100-003-F01 Measured 1976 AGM: .66 $\mu g/m^3$

LOCATION: 117.1 20.7

	CONTRIBUTIONS $\mu g/m^3$ - AAM				
POINT SOURCES	BASE	COMPLIANCE	STRATEGY	REDUCTION	1990
Oil Fired Boilers	3.3	3.0	3.0	0	5.5
Bagasse Fired Boilers	0.1	0	0	0	0
Stationary Engines	0.2	0.2	0.2	0	0.4
Processes	1.0	0.7	0.7	0	1.3
Nonprocesses	2.9	2.8	0.3	2.5	0.5
Quarrying, Sand/Gravel	8.5	1.9	0.1	1.8	0.2
Asphalt Dryers	0.2	0	0	0	0
Incinerators	0.1	0	0	0	0
TOTAL	16.3	8.6	4.3	4.3	7.9
AREA SOURCES					
Agricultural Burning	5.1	5.1	0	5.1	0
Open Burning	3.0	3.0	0	3.0	0
Paved Roads	11.4	11.4	11.4	0	20.5
Unpaved Roads	19.6	19.6	19.6	0	16.1
Other Sources	2.3	2.3	2.3	0	4.1
TOTAL	41.4	41.4	33.3	8.1	40.7
GRAND TOTAL	57.7	50.0	37.6	12.4	48.6
Corrected Annual Geometric Mean	57.0	49.0	37.0	-	48.0

PREDICTED TSP CONCENTRATIONS - $\mu g/m^3$ (1)
GUAYANILLA-MAGAS ARRIBA



(1) No growth is accounted for in the compliance and strategy cases; the 1990 case represents unconstrained economic growth which is shown for reference only.

FIGURE IV-14

TABLE IV-11

SOURCE CATEGORY CONTRIBUTIONS TO
PREDICTED AIR QUALITY

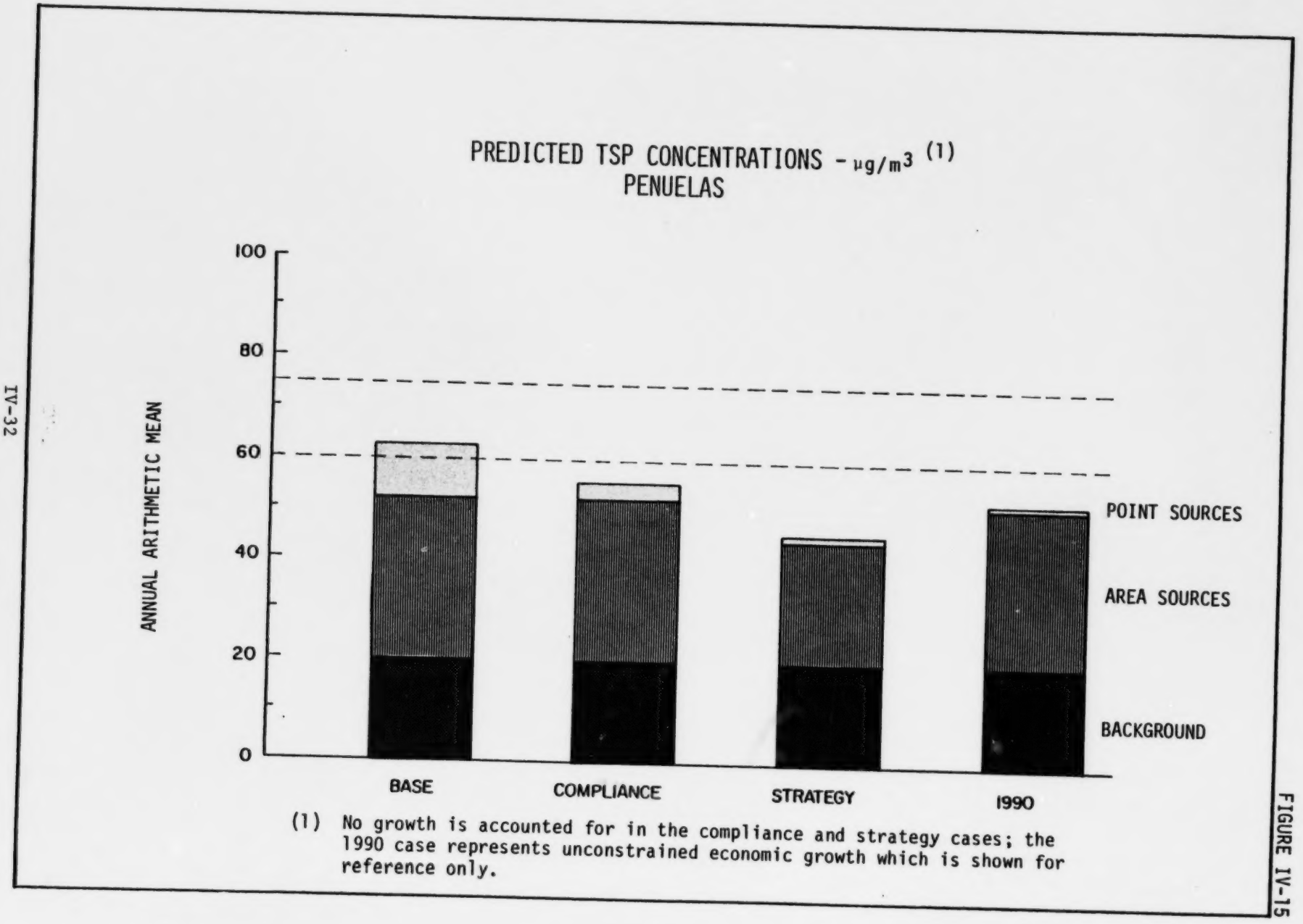
PREDICTION SITE: PENUELAS

SAROAD IDENT: 40-1885-002-F01 Measured 1976 AGM: 74 $\mu g/m^3$

LOCATION: 121.9 24.6

	CONTRIBUTIONS $\mu g/m^3$ - AAM				
POINT SOURCES	BASE	COMPLIANCE	STRATEGY	REDUCTION	1990
Oil Fired Boilers	0.3	0.2	0.2	0	0.4
Bagasse Fired Boilers	0.1	0	0	0	0
Stationary Engines	0	0	0	0	0
Processes	0.1	0.1	0.1	0	0.1
Nonprocesses	1.6	1.5	0.1	1.4	0.3
Quarrying, Sand/Gravel	6.3	1.5	0.1	1.4	0.1
Asphalt Dryers	0.2	0.1	0	0.1	0
Incinerators	0	0	0	0	0
TOTAL	8.6	3.4	0.5	2.9	0.9
AREA SOURCES					
Agricultural Burning	4.7	4.7	0	4.7	0
Open Burning	2.9	2.9	0	2.9	0
Paved Roads	8.9	8.9	8.9	0	16.0
Unpaved Roads	12.6	12.6	12.6	0	10.3
Other Sources	1.8	1.8	1.8	0	3.2
TOTAL	30.9	30.9	23.3	7.6	29.5
GRAND TOTAL	39.5	34.3	23.8	10.5	30.4
Corrected Annual Geometeric Mean	38.0	33.0	23.0	-	29.0

*First quarter 1976



(1) No growth is accounted for in the compliance and strategy cases; the 1990 case represents unconstrained economic growth which is shown for reference only.

FIGURE IV-15

Unless unregulated major industrial development occurs in any of these municipalities, their air quality levels will not exceed the primary TSP standard of 75 $\mu g/m^3$. Any major sources locating in these areas will have to meet Prevention of Significant Deterioration (PSD) permitting requirements. Based on our analysis, all of the PSD increment of 19 $\mu g/m^3$, annual basis, is available. If the increment is used entirely, the maximum level in 1990 would be about 68 $\mu g/m^3$ (49 + 19) for Dorado, which has the highest 1990 levels of all maintenance areas suggested for de-designation. Since the EQB is adopting the PSD permitting authority, it appears that air quality levels in these areas will continue to remain below Commonwealth and Federal levels.

There are several areas which should be further analyzed to assure that primary standards will indeed be maintained after the December 31, 1982 attainment date as described in the Clean Air Act Amendments of 1977. These areas are summarized below:

Maintenance Areas	Air Quality Levels ($\mu g/m^3$, AGM)	
	Base Case 1976	1990
Catano (including San Juan)	110	87
Ponce	94*	74
Guayanilla-Penuelas	87	68
Guanica	82*	63
Guayama	69	50
Yabucoa	75	72

*These areas appeared to have concentrations higher than the primary TSP standard but were not designated as nonattainment areas because there was not sufficient monitoring data to verify the computer predicted air quality levels.

Based on the predicted growth rates, all of the above areas will maintain the primary standard through 1990 except for the Catano-San Juan area. However, for this area the maximum level was influenced greatly by the grain mills, and it was assumed that a 95% expansion to these mill operations would be made between 1976 and 1990. Nearly doubling the capacity (by 95%) is not possible considering the physical size of these plants, and, therefore, a more reasonable estimate is likely to be lower than the 87 $\mu g/m^3$ predicted for this area. If there were no expansion

of the mill operations, the air quality level could be as low as 57 $\mu g/m^3$ in 1990.

The Catano, Ponce, Guayanilla-Penuelas, Guanica, and Yabucoa areas do not meet the secondary standard of 60 $\mu g/m^3$, AGM. This 60 $\mu g/m^3$ limit is not really a standard but is to be used as a guide in assessing attainment of the 24-hour secondary standard of 150 $\mu g/m^3$. Because of the methodology used in these analyses, ES has used the 60 $\mu g/m^3$ annual guide in determining whether further reduction will be required to meet the secondary standard. The areas identified above should be studied further to not only demonstrate attainment of the primary standards, but also attainment and maintenance of the secondary standard.

SENSITIVITY ANALYSIS OF 1990 PREDICTIONS

This analysis was based on several key assumptions about expected new industrial and domestic increases in particulate emissions. A sensitivity analysis was performed assuming a growth rate of 6% per year instead of about 4%. In addition, point sources were assumed to grow at 6% per year. For this special analysis, the predicted 1990 air quality levels were highest in the San Juan and Ponce areas and exceeded the primary and secondary standards in many other areas. The highest value (island-wide) was 110 $\mu g/m^3$ AGM. These predictions were based on all proposed EQB strategies being implemented by 1990.

A second sensitivity analysis was performed to show the air quality level if no strategies were implemented by 1990. Emissions were projected from the compliance scenario assuming a compounded annual growth rate of 4% for area sources and 4.5% for point sources. The maximum value for the San Juan area was about 170 $\mu g/m^3$, AGM; and, for the Ponce area, 100 $\mu g/m^3$. Indeed, TSP levels would increase substantially unless EQB adopts new emission regulations.

CHAPTER V

CONTROL STRATEGY DEVELOPMENT

This section of the report is intended to highlight some of the key results and conclusions that have been discussed thus far. Special consideration is given to the relative improvement in air quality that could be derived if each or all of the suggested control strategies were implemented by the EQB. The four cases studied were:

- o Existing conditions;
- o Compliance with current EQB regulations;
- o Proposed control strategies developed by EQB; and
- o Projections of emissions under the new regulations to the year 1990.

The results of the study indicate that a substantial improvement could be made in the particulate air quality levels for Puerto Rico if the proposed strategies were implemented. It is incumbent upon EQB and the Board Directors to select the most beneficial and cost-effective strategies for inclusion in the January 1979 SIP to be submitted to EPA. The selection of those strategies should be based on engineering analysis and the results discussed in this report. However, other social, political, economic, and energy considerations must be given to each of the control strategies in order to determine if these are realistic measures for control of air pollution in Puerto Rico. Those considerations have not been evaluated in this report. Only the air pollution engineering aspects of the control strategies have been evaluated.

COMPARISON OF EMISSION DATA

Table V-1 summarizes the emissions for each of the control strategies tested for the three general areas of the island. The northeastern study area comprises the San Juan metropolitan area and the southern study area comprises the Ponce metroplitan area, including Penuelas and Guayanilla. The northwestern study area contains the cities of Mayaguez, Arecibo-Barceloneta, and Aguadilla. In the San Juan area, most of the emissions came from point sources. Oil fired boilers were the largest single source of particulate emissions in several municipalities in the northeastern study

TABLE V-1

SUMMARY OF PARTICULATE EMISSIONS FOR THE CONTROL STRATEGIES TESTED

PARTICULATE EMISSIONS (tons per year)

STRATEGY	NORTHEASTERN STUDY AREA[a]				SOUTHERN STUDY AREA[b]				NORTHWESTERN STUDY AREA[c]			
	BASE	COMPLIANCE	STRATEGY	1990	BASE	COMPLIANCE	STRATEGY	1990	BASE	COMPLIANCE	STRATEGY	1990
Oil Fired Boilers	7,300	7,008	7,008	12,593	9,782	7,008	7,008	12,848	219	219	219	365
Solid Fuel Boilers	183	110	73	73	5,767	1,132	986	986	2,920	548	474	474
Nonprocess Sources	4,234	3,650	584	949	3,468	3,285	256	475	986	986	36	36
Quarrying, Sand/Gravel	3,103	1,497	219	365	3,249	986	73	110	840	292	36	36
Asphalt Dryers	2,628	2,482	219	219	1,095	803	767	767	146	146	73	73
Agricultural (Cane) Burning	1,387	1,387	0	0	4,526	4,526	0	0	3,285	3,285	0	0
Open Burning	6,169	6,169	0	0	1,971	1,971	0	0	1,788	1,788	0	0
Other	16,095	14,527	14,257	23,797	23,688	23,177	23,177	28,395	8,504	8,504	8,504	14,016
TOTAL	41,099	36,830	22,630	37,997	53,546	42,888	32,267	43,581	18,688	15,768	9,342	15,000

[a] Includes the municipalities of San Juan, Catano, Bayamon, Guaynabo, Toa Baja, Dorado, plus several others.

[b] Includes the municipalities of Ponce and Guayanilla, plus several others.

[c] Includes the municipalities of Aguadilla, Arecibo, Mayaguez, plus several others.

area. Nonprocess sources accounted for a substantial portion of emissions as well. Paved and unpaved roads, and open burning accounted for the major area source emissions in the San Juan metropolitan area.

Table V-1 shows the reductions in emissions associated with meeting the existing Puerto Rico regulations. In the northeastern and southern study areas, a significant reduction in emissions resulted from complying with the visible emission regulation. Oil fired boilers and a number of industrial processes are required to meet 20% plume opacity restrictions. Supporting data from EPA publications for oil fired boilers and other sources were evaluated to develop a relationship between opacity and mass emission rates. Specific opacity limitations, as spelled out in the EQB regulations, were then applied to each affected source on a mass emission basis.

Emissions were substantially reduced when all of the proposed EQB strategies identified earlier were applied to the compliance inventory. It should be pointed out that these reductions were for the base year 1976 operating conditions. In essence, it represents a hypothetical estimate, as if these controls were available and were applied to sources operating in 1976. These emissions are also summarized in Table V-1.

In order to check the impact of growth and the suitability of these emission reductions for this area over some period of time, projections were made through the study year 1990.

IMPACT ON AIR QUALITY

EPA's air quality dispersion model was used to predict ambient levels of total suspended particulate matter for the study areas. The calibration/validation effort was performed using field measured ambient air quality data collected by EQB. The comparison of the computer predicted base year results with the measured year values was favorable. This comparison validates the use of a dispersion model like AQDM to predict accurately changes in the air quality resulting from changes in air pollution emissions.

The changes that were described in Table V-1 were input to the model to determine what the subsequent decrease in ambient TSP levels would be. The results are summarized in Table V-2. For each of the several strategies that were analyzed, the improvement in air quality was summarized.

TABLE V-2

SUMMARY OF AIR QUALITY IMPROVEMENTS

FOR THE CONTROL STRATEGIES TESTED

STRATEGY	IMPROVEMENTS IN AIR QUALITY[a,b] ($\mu g/m^3$, AGM)	
	RANGE	AVERAGE
Oil Fired Boilers	0 - 0.1	<0.1
Solid Fuel Boilers	0 - 0.1	<0.1
Nonprocess Sources[d]	1.4 - 80.6	18
Asphalt Dryers	0 - 8.4	4
Quarrying, Sand/Gravel[d]	0.8 - 2.2	1
Agricultural (Cane) Burning[c]	4.7 - 5.5[c]	5[c]
Open Burning	2.9 - 12.6	7

[a] Based on the detailed analysis of nine monitoring stations.
[b] Improvement from the compliance scenario
[c] South coast only
[d] The new regulation for nonprocess sources and quarrying is the same

The range in improvement noted in the table refers to the reduction in micrograms per cubic meter for total suspended particulate levels that was expected when compared to the compliance scenario.

It should be pointed out that bringing point sources into compliance with present EQB emissions reduces ambient air quality levels of TSP substantially. In this analysis, the predicted air quality for the compliance scenario showed a maximum of about 105 $\mu g/m^3$, AGM in the Catano area. This maximum value under the compliance case still exceeded the Puerto Rico and Federal primary standards for particulate matter. In Guayanilla-Penuelas, the predicted levels were just within the primary standard of 75 $\mu g/m^3$, AGM. As a result, further reductions in emissions are required in order to attain and maintain clean air levels in Puerto Rico.

The table clearly shows that the greatest benefit in air quality is derived from the nonprocess emission regulation developed by EQB. Another point source category, asphalt dryers, also showed that a substantial improvement in air quality would result in the proposed EQB regulations were implemented. The elimination of open burning and agricultural cane burning also leads to a general improvement in air quality over the entire island.

Very little benefit is gained from the tightening of regulations concerning oil fired boilers and solid fuel boilers. EQB should consider the little benefit derived from these types of regulations. Obviously, they are not cost-effective measures for reducing TSP levels in Puerto Rico.

Implementing all control strategies resulted in a maximum AGM concentration in the Catano area of about 55 $\mu g/m^3$ AGM. In Guayanilla-Penuelas, the concentrations were higher, probably due to the arid nature of the environment in that area. The maximum concentration in the Guayanilla-Penuelas area was about 60 $\mu g/m^3$, AGM. In the Yabucoa area, the maximum concentration was 45 $\mu g/m^3$. In all parts of the island, predicted concentrations equaled or were within the EQB and Federal primary and secondary ambient air quality standards. The maximum 24-hour concentration predicted using Larsen's technique was about 80 $\mu g/m^3$. The EQB and Federal 24-hour standard for particulate matter was 260 $\mu g/m^3$ for the primary standard and 150 $\mu g/m^3$ for the secondary standard.

The Clean Air Act requires that the standards be attained as expeditiously as practicable. It further requires that air quality levels shall be maintained for a period of 10 years after the attainment date. Attainment with the standards is expected in 1980. Projections were made to the year 1990. With all strategies implemented, the maximum projected concentration on the island in 1990 was predicted to be 90 $\mu g/m^3$ and occurred in the Catano area. A worst case methodology, which assumed that all new growth occurred at existing plants, was used for the 1990 analysis. By spreading the growth out to new plants, air quality improves. ES does not recommend that new strategies be developed for the Catano area but does

encourage the EQB to plan locations of new growth carefully in order to maintain the primary air quality standard. We suggest the adoption of an emission offset policy similar to the one currently being used by EPA.

SUMMARY OF CONTROL STRATEGY DEVELOPMENT TESTS

An accurate point and area source emission inventory had been developed by the EQB and ES. Information on population increases and industrial growth was obtained from industry and governmental agencies. These data were used to preduct future industrial activity and emissions.

An analysis was performed to show what effect bringing point sources into compliance with existing EQB regulations would have on air quality. A substantial benefit occurred; ambient air quality levels are expected to improve considerably in the San Juan area. Significant improvements were also noted in the Ponce metropolitan area.

The atmospheric dispersion model was used as a tool to predict improvements in air quality that could be obtained from changes in emissions. The reductions in emissions were expected to result from new emission regulations that had been proposed by the Puerto Rico Environmental Quality Board. Specifically, six regulations covering point and area source-type emissions were proposed and evaluated.

Several proposed EQB strategies were evaluated for their potential improvement in air quality. Of the six tested, four showed that substantial improvements could be made if the strategies were implemented. Two strategies showed little or no potential improvement in ambient air quality levels. The greatest benefit was derived from the proposed nonprocess source emission regulation. Improvements in air quality of about 18 $\mu g/m^3$ annual average were noted throughout the island where these types of sources were located.

It is recommended that four of the six regulations tested be adopted and implemented in Puerto Rico. With present emission conditions, the four regulations will provide an adequate margin of safety in attaining and maintaining primary standards.

CHAPTER VI

SUMMARY AND CONCLUSIONS

1. Engineering-Science conducted an analysis to determine if proposed emission-reduction strategies developed by EQB would be effective in reducing ambient total suspended particulate (TSP) concentrations in Puerto Rico to a level within Commonwealth and Federal air quality standards. The analysis included the development of source-receptor relationships and computer modeling of air quality over a major portion of the island for several scenarios.

2. Four cases were studied:
   a) Existing conditions
   b) Compliance with current EQB regulations
   c) Proposed EQB regulations
   d) Projections to 1990

3. For the compliance case, emissions from all point sources exceeding the allowable emission rate as specified by current EQB regulations, were reduced to the maximum allowable limit.

4. The proposed EQB regulations evaluated were:

a) Oil fired boilers	0.30 lb/mmBtu
b) Solid fuel boilers	0.25 lb/ mmBtu
c) "Nonprocesses"*	99% control
d) Quarrying, sand/gravel	99% control
e) Asphalt dryers	0.12 gr/dscf
f) Elimination of agricultural burning	
g) Elimination of open burning	

5. For the projection to 1990, point source emissions were increased by a growth factor based on Commonwealth and Federal data. The area source growth factor was 1.80 except for unpaved road emissions which were decreased by 0.18 to reflect historical paving trends on the island. All point source growth was assumed to occur in place.

---

*Manufacturing processes not involving a chemical reaction.

6. The predicted air quality for existing conditions exceeded Commonwealth and Federal ambient air quality standards for several municipalities in Puerto Rico. The predicted results compared favorably with EQB field-measured data, thereby validating the source-receptor relationship established by the mathematical dispersion model.

7. For the compliance case, predicted TSP levels were reduced substantially throughout the Commonwealth, but concentrations in some parts of the island still exceeded air quality standards.

8. With the proposed EQB strategies, ambient TSP levels were reduced further, beyond those levels predicted for the compliance case. In this case, all standards (primary, secondary, long term, and short term) were met. Table VI-1 summarizes all predicted results.

9. Of the many strategies tested, four showed considerable TSP reductions, while all others resulted in an improvement of $<2\ \mu g/m^3$. The four noteworthy regulations were for

   - o Nonprocess sources
   - o Open burning
   - o Agricultural burning
   - o Asphalt dryers

10. A check was made to insure that the new EQB regulations would adequately maintain standards through 1990 in the maintenance areas. The predicted air quality for 1990 was below the primary TSP ambient air quality standard except for the Guaynabo monitoring station. Considering the worst case methodology used to forecast emissions, it is doubtful whether the predicted level will ever be reached at this location. These predicted concentrations for 1990 illustrate the importance of environmental planning. It is suggested that an emission offset policy be developed by EQB to accommodate new growth in a fair and effective manner.

11. In summary, bringing sources into compliance with current EQB regulations improves air quality significantly. However, in order to attain and maintain primary standards, the proposed regulations will have to be adopted.

TABLE VI-1

SUMMARY OF PREDICTED TSP RESULTS[a]

STUDY AREAS	MAXIMUM ANNUAL GEOMETRIC MEAN CONCENTRATION ($\mu g/m^3$)[b]			
	BASE	COMPLIANCE	STRATEGY	1990
DESIGNATED NON-ATTAINMENT AREAS				
Catano	110	105	56	87
Guayanilla-Penuelas	87	73	60	68
MAINTENANCE AREAS				
Mayaguez	39	39	29	39
Caguas	41	37	24	29
Guanica	82	69	59	63
Lares-Utuado-Adjuntas	39	34	29	34
Aguadilla	44	39	29	41
Arecibo-Barceloneta	29	27	19	29
Guayama	69	62	53	50
Yabucoa	75	49	47	72

[a] The ambient air quality standard is 75 $\mu g/m^3$, annual geometric mean.

[b] All model predicted results were converted to annual geometric mean concentrations for comparison with the standards.